AdvTech AirPollution

NEW TEACHING AND LEARNING METHODS FOR THE POST-PANDEMIC TIME

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CONTENTS

INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) education, a form of interdisciplinary education, successfully applies competency-based learning to the education of the younger generation at all levels. Specialized universities that prepare specialists in this field make an important contribution to promoting the development of human capacity and talent, to improving the employability of young people and their ability to solve complex problems. The transformation of education is constant, technological advances, new concepts and challenges and global situations such as the COVID-19 pandemic require the existence of educational models that go with the same speed of change and adaptation. This requires educators to be increasingly prepared and open, receptive, ready to face current challenges through continuous learning. Circumstances such as the 2020 pandemic have in many cases transformed traditional educational models, including technological and pedagogical innovations that have emerged in response to the changes we have had to experience following events related to COVID-19.

A team of faculty from four universities - University of Craiova (UCv), Plovdiv University (PU), Matej Bel University Banská Bystrica (UMB) and Adana Alparslan Türkeş Science and Technology University (ATU) are working on the project „Applying some advanced technologies in teaching and research, in relation to air pollution". Part of the project activities are related to the application of modern technologies in the students' education, future engineers and scientists. This book presents their research experiences, views and ideas about the place and role of some advanced technologies and pedagogical approaches in the learning process during the years during and after the pandemic. Topics related to the use of online-based pedagogical environments, online conferencing and collaboration platforms are addressed. Good practices related to integrative and research approaches and strategies in training future engineers and scientists are shared. Some of the common challenges in learning practice during the COVID-19 pandemic are addressed. In recent years, the development of technology has greatly influenced the traditional course of the educational process in universities that prepare engineering majors and specialists in science. This impact was amplified during the pandemic as their embedding in the learning environment brought changes that helped us cope with the learning process in the pandemic environment. Every change is an opportunity for innovation.

The role of new technologies and their place in higher education created conditions for innovative application of familiar approaches and methods. They created proper conditions for the distance form of education to be not only an alternative, but predominant. Their wide application allowed us to appreciate the good opportunities they offer us for more active involvement of our students during self-study in project activity. Conducting online training for a long time brought to the attention of the educators' topics related to the need for access to electronic means for the quality conduct of the training and the need-to-know different educational platforms and new educational technologies. Placed in unprecedented opportunities for teaching and learning, educators realized that there was much to learn—to better understand uncertainty, to be willing to take the risks of change, and to appreciate the possibilities and importance of new technologies.

This book shares good practices and some ideas of professors who teach students in engineering majors and physics from the four universities - UCv, PU, UMB and ATU on how to use new technologies successfully in the educational process. In general, the experience of conducting training during pandemic has shown that moving away from traditional forms and ways of conducting it is not fatal for anyone and that the future is seen as training - combining the best of face-to-face training and electronic distance learning.

The educational possibilities of some of the new technologies are described in Chapter 1. The role and place of some SMART technologies for training of students in physics and technology is discussed in this chapter. This chapter describes some of the applications of augmented reality in the education of future engineers and physicists/scientists that have been realized in educational practice. Some didactic possibilities of artificial intelligence in the training of engineers and scientists are also examined. Attention is paid to the possibility of conducting experiments with remote access. The formation of practical skills and competencies for experimental work is important for future engineers and scientists. This chapter also describes learning technologies such as hybrid and blended learning, which remain relevant in the post-pandemic era. Understanding the differences between these and knowing their advantages and disadvantages is helpful for educators when making choices about their teaching style. The flipped classroom technology has been known to educators since before the pandemic. At that time, its place was mainly related to higher education, but its application as an approach was not widespread. The experience during the pandemic showed that the implementation of the flipped classroom as an approach has a place in all levels of education, but it has a special place in the future training of scientists and engineers, and it deserves the educators' attention. In the first chapter of the book, attention is paid to this approach, some questions about the technology of its applying are discussed and the corresponding activities of faculty and students are described.

The second chapter is focused on the place and role of cloud technologies in higher education. The experience of using the most popular educational platforms is shared, and on this basis, an assessment of some of their educational possibilities is made. The application of new technologies in the learning process offered a new perspective on the use of known educational methods such as project-based learning, research and integrative approaches.

The application of project-based learning is closely related to the integrative and exploratory approaches to learning. The role of the integrative approach in the preparation of future engineers and scientists, as well as the experience of the faculty from the four universities, are described in Chapter 3.

It is a well-known principle that universities teach by doing science. Understanding the role and place of student involvement in research is part of the student learning experience at the four universities. The examination of some challenges posed by the form of training during the pandemic for the involvement of students in scientific research is described in Chapter 4.

Despite the accumulated experience that has helped us in recent years to deal more calmly with conducting the educational process, despite the progress we have in how to use modern technologies, we are aware that there are still challenges and unresolved problems ahead of us.

In this book, we share some of our ideas about the new challenges in educating STEM university students in the post-pandemic period. We believe that the modern educator should be aware of the ways to organize the learning process both remotely in an online environment and through a blending and hybrid form. He/she must be aware of how to most effectively integrate new technologies with traditions in the preparation of future engineers and scientists to conduct quality education and be prepared for unforeseen situations.

CHAPTER 1

THE ROLE AND PLACE OF SOME SMART TECHNOLOGIES FOR TRAINING OF STUDENTS IN PHYSICS AND TECHNOLOGY

New digital technologies have undoubtedly entered in education rapidly, forced by the events accompanying the COVID-19 pandemic. The transformations in education that they caused led to the consideration of new educational concepts. One such concept is SMART learning, which is seen as technologically enhanced education incorporating technological enhancements. As a new educational paradigm, SMART learning is based on SMART devices, which create SMART learning environments and SMART technologies. Connecting modern technologies in a network allows them to share information with each other or work together. SMART technologies can thus be more energy efficient and synchronized in their functions when coordinated and shared. The collection of SMART technologies and the potential they offer is often referred to as the Internet of Things (IoT) (Zhu et al., 2016).

SMART technologies mean such integration of computer and telecommunication technologies, which allows automation, adaptation of processes and remote access to them. SMART technologies are mostly associated with artificial intelligence, augmented and virtual reality, Internet of Things (IoT), remote experiment, cloud technologies. SMART technologies can be media or tools for accessing educational content, provide the application of various educational methods (exploratory, integrative, etc.), provide communication and collaboration, construction, expression and evaluation, personalization of learning. Their importance in the education system at all levels already in the post-pandemic time cannot be ignored. Their knowledge by trainers and successful application in the learning process is a condition for its modernization and improvement.

1.1. Artificial intelligence as a trend in STEM education (Zhelyazka Raykova, Janka Raganova)

Importance of Artificial Intelligence (AI)

The development of Information and Communications Technology (ICT) in recent years has led to the creation of AI, which are now part of our daily lives. AI is changing the way we search for information, how we communicate with each other, even our behaviour. This technology is continuously updated and widely used in various fields (Pannu, 2015). In the process of development, more and more researchers pay attention to the importance of this technology for education. In the context of the COVID-19 pandemic, all educational institutions used learning management systems (LMS) such as Moodle, Google, Microsoft Teams, etc. The number of active users of massive open courses (MOOCs) for online learning, such as Coursera.com. is getting bigger, which shows that e- and distance learning methodologies are valued by society. At the same time, we observe applications of the latest advances in virtual reality (VR), augmented reality (AR) and artificial intelligence (AI) and its application in the educational process. Applied robots are also entering practice, which allow learners to work together with their teacher, or colleagues to work together (chatbots, cobots) (Chassignol, et all. 2018).

In the Stanford University "AI Report" for 2021, it is noted that in 2020, one in every five computer science students who graduated with PhD degrees specialized in AI/ML (Machine Learning) in USA, the most popular specialty in the past decade. It is also noted that: "An AI Index survey conducted in 2020 suggests that the world's top universities have increased their investment in AI education over the past four years. The number of courses that teach students the skills necessary to build or deploy a practical AI model on the undergraduate and graduate levels has increased by 102.9 % and 41.7 %, respectively, during the last four academic years."

In the European Union, the majority of specialized AI academic offerings are taught at the master's level; "Robotics and automation" is by far the most frequently taught course in the specialized bachelor's and master's programs, while Machine Learning (ML) dominates in the specialized short courses (Index Report 2021, Artificial Intelligence Stanford University).

A 2021 report by UNESCO, which is a guide for policymakers in education, assessed the importance of AI with the statement: "Only in the last five years, due to some remarkable successes and their disruptive potential, artificial intelligence (AI) has moved out of the backwaters." of academic research to the fore in public discussions, including those at the UN level. In many countries, artificial intelligence is pervasive in everyday life, from personal smartphone assistants to customer support chatbots, from entertainment recommendations to crime predictions, and from facial recognition to medical diagnoses" (Miao, F. Holmes, W. Huang, R., Zhang, H. 2021). It is indeed evident, as noted by the United Nations Educational, Scientific and Cultural Organization (UNESCO), that AI has permeated various sectors of society, particularly in the education sector, as discussed for example, instruction or teaching methods, approaches and tools (UNESCO, 2019).

AI offers the possibility of using a huge resource of knowledge that can be structured in an appropriate way and used in the learning process. They are ways to individualize and personalize learning and can have a supporting role in designing and implementing curricula. AI techniques affect in the following areas - deep learning, data mining, solving complex problems. Intelligent learning systems (ITS) are a promising integrated educational tool for personalizing formal education using intelligent instruction and feedback. AI has been widely used in the field of education and has shown significant advantages in application that has a profound impact on the learning process and classroom management (Chassignol, 2018).

The application of AI algorithms and systems in education is gaining more and more interest from year to year. A reference to the number of articles published in the topics "AI" and "Education" from Web of Science and Google Scholar published in 2015-2019 shows that they represent 70 % of all indexed documents (Chen et al, 2020). In the work of Guo et al., 2021, it is described that in recent years, research on artificial intelligence (AI) applications in education (AIED) has increased extremely during the years 2013-2019. The research done is on 1173 relevant publications collected from the databases of the Web of Science Core Collection (Expanded and the Social Science Citation Index). It was found that the number of citations of articles related to AI in study has grown exponentially from 4 in 1986 to 2,714 in 2019. The same study also identifies research trends in this field (AIED). They are predominantly multidisciplinary in nature, integrating modern achievements in computer science, education, psychology and engineering, neuroscience and pedagogy (Guo et al., 2021). According to the study by Sharma et al. (2019) the use of AI in education represents an opportunity for a major revolution in various aspects of education.

All these convinces us of the relevance of the problem of the application of AI in education. AI enters the practice of the universities that participate in the ERASMUS+ project *Applying some advanced technologies in teaching and research, in relation to air pollution* and defines the latest trends in educational technologies.

Definitions of AI. A generally accepted single definition of AI is not found in the literature. The boundaries and scope of this concept are wide and variable. In the textbook "Artificial Intelligence, Human Rights, Democracy and the Rule of Law" published by the Alan Turing Institute of the United Kingdom, which is based on the position of the Council of Europe, Ad Hoc Committee on Artificial Intelligence (CAHAI) https://www.coe.int/en/web/artificial-intelligence/cahai) adopts the following definition: "AI systems are algorithmic models that perform cognitive or perceptual functions in the world previously reserved for human beings to think, judge, and reason." AI systems are algorithmic models that carry out cognitive or perceptual functions in the world that were previously reserved for thinking, judging, and reasoning human beings (Leslie et al., 2021).

A definition of AI given by UNICEF, agreed by the Organization for Economic Co-operation and Development (OECD) is as follows: "AI refers to machine-based systems that can, given a set of human-defined objectives, make predictions, recommendations, or decisions that influence real or virtual environments. AI systems interact with us and act on our environment, either directly or indirectly. Often, they appear to operate autonomously, and can adapt their behaviour by learning about the context" (OECD, 2021).

Artificial Intelligence was first mentioned at a seminar at Dartmouth College in 1956. From its earliest days, AI researchers have been interested in two parallel approaches. The first, the so-called *"symboli"* AI approach focuses on encoding the principles of human reasoning and encoding the knowledge of experts, resulting in "expert systems". This approach is often referred to as a *"rule-based"* or *"good old-fashioned AI"* (GOFAI) approach. The second is also based on the structure of the human brain (neural networks) and which processes and draws conclusions based on large amounts of data. This approach, also called connected artificial neural network (ANN)-like, is one of several data-driven approaches (such as Support Vector Machine (SVM), Bayesian networks (network models), and decision trees) that are known as Machine Learning (ML).

At the beginning of the 21st century, thanks to faster processors and the availability of huge amounts of data (mainly obtained from the Internet), ML became the dominant approach in AI. ML is usually associated with automatic translation between languages through translation or image recognition applications. It is accepted that ML is considered as a subset of AI. In AI, the use of data serves to build a model, which is subsequently upgraded or not. AI uses ML data for its development. There are still many AI applications that do not use ML. (Miao et al., 2021). It is important to note that AI should not be seen as a combination of purely technical terms, but as something constructed from complex social processes (Eynon and Young, 2021). In other words, when considering AI, one must consider the combination of both human and technological dimensions.

AI is the ability of machines to adapt to new situations, compare with emerging situations, solve problems, answer questions, plan a device and perform various other functions that require some level of intelligence that is observed in humans (Coppin, 2021). Another definition given by Whitby (2008) sees AI as the study of the behaviour and intelligence of animals and humans and machines in an attempt to create similar behaviour through computers and related technologies. According to Wang et al. 2015, "Artificial Intelligence is that activity devoted to making machines intelligent, and intelligence is that quality which enables an entity to function appropriately and predictably in its environment."

Another key definition of this new technology presented as: (Ma et al., 2014): AI is "the area of computer science devoted to solving cognitive problems often associated with human intelligence, such as learning, problem solving, and pattern recognition". AI is "the theory and development of computer systems capable of performing tasks that would normally require a human intelligence, such as visual perception, speech recognition, decision making and translation between languages."

Chassignol et al. provide another two-pronged definition and description of AI. They determine AI as a field and theory. As an area of research, they define

AI as a field of study in computer science whose pursuits are aimed at solving various cognitive problems commonly associated with human intelligence, such as learning, problem solving, and pattern recognition and subsequent adaptation. The understanding of Chassignol et al. for AI as a theoretical framework is related to the idea that it guides the development and use of computer systems with the capabilities of human beings to perform tasks that require human intelligence, including visual perception, speech recognition, decision making, and translation between languages Chassignol et al., 2018). Other scholars, defining AI, bring to the fore almost similar elements or characteristics of AI. Sharma et al, define AI as machines that can approximate human reasoning.

According to Pokrivcakova, AI is the result of many decades of research and development, bringing together system designers, data scientists, product designers, statisticians, linguists, cognitivists, psychologists, educational experts and many others to develop educational systems with a certain level of intelligence and the ability to perform a variety of functions, including helping educators and supporting learners to develop their knowledge and flexible skills for an ever-changing world. Also, according to her, AI uses enhanced capabilities of programs and software, such as algorithmic machine learning, which provides machines with the ability to perform various tasks that require human intelligence and the ability to adapt to the immediate environment (Pokrivcakova, 2019).

Therefore, AI in education is designed to do more than normal computers and related functions. AI in its entirety is replacing the conventional understanding of the various technological applications in education, web-based, online, distance and computer-assisted teaching and learning courses. In agreement, Pokrivcakova noted that AI in education takes the form of intelligent systems with adaptive capabilities these principles and characteristics of systems allow AI in education to perform a wide range of tasks traditionally or conventionally performed by instructors, while enhancing the learning experience of students by teaching students and personalizing learning according to student expectations and needs.

Similar views on AI are given by Wartman et al., who define artificial intelligence as the ability of computers and machines to imitate human cognition and actions. Recently, AI and machine learning have been increasingly applied in mobile devices. This is mainly related to the goal of improving the quality of computing and creating opportunities for new applications, such as facial unlocking, speech recognition, translation of some (non-machine) language and the use of virtual reality. The technical development of AI in mobile devices takes mobile education to a higher level, which provides convenience by aiding learning (Chen et al., 2020).

Timms postulates that Artificial Intelligence in Education (AIED) is not just computers or desktop computers and other computing applications as commonly understood. It focuses the understanding of the use of AI through embedded computing systems, such as in smart classrooms and cobots (Timms, 2016).

Chassignol et al. note that AI in education has taken the form of computers and related technologies, such as the Internet and the World Wide Web. According to them, AI in the education sector is moving from the use of ordinary computers to embedded intelligent systems, such as robots or fellow robots (cobots) that work with an instructor or trainers or independently to perform teacher-like functions. Chassignol et al. highlight the broad application of AI in various fields, including content development, teaching methods, student assessment, and teacher-student communication. According to them, AI is widely applied in curriculum development and content customization, teaching and pedagogical methods, assessment and communication exchange between educators and students. They also present examples of different AI platforms and applications, such as Interactive Learning Environments (ILE), which are used to manage, provide feedback and exchange between educators and students. AI also includes intelligent learning systems, such as ACTIVE Math, MATHia, Why2Atlas, Comet and Viper, which have been used at different levels of the education system by instructors of different subjects at different levels of education, as well as widely used in learning assessment, to evaluate and improve pedagogical tools.

Sharma et al. observe that AI in education has taken the form of adaptive learning systems, intelligent learning systems, and other systems that improve the quality of administrative processes, instruction, and learning.

Mikropoulos and Natsis in their paper also describe another aspect of AI in instruction, virtual reality (VR) and three-dimensional (3-D) technology, noting that VR offers tremendous opportunities for the learning process, integrating simulation and 3-D technology and provides learners with an opportunity for experiential learning (Mikropoulos & Natsis, 2011). Summarizing the definitions of artificial intelligence mentioned above, we assume that it is related to the development of computer machines that have some level of intelligence and can perform some human functions such as learning, decision making and adapting to the environment. This is precisely the key characteristic of AI that determines its application in education - to demonstrate some level of intelligence and perform a wide range of functions and capabilities that require human capabilities. AI is a culmination of computers related to computer technology, machines, innovation and ICT.

AI Impact on Education (AIED). The impact of AI on education is being actively studied by the scientific community. According to Chassignol et al, AI finds application in educational institutions in different ways, which can be grouped into three areas: automation of administrative processes and tasks, activities related to teaching (curriculum and content development, instructions, etc.) and activities related to learning. This team also adds that another important AI option tied to the application of AI in education concerns overcoming the physical barriers posed by national and international borders, brought about by the fact that learning resources are now located on the Internet and the World Wide Web. Online learning or the use of web-based learning platforms allows it to be accessible to every citizen of the world using the Internet. Using other aspects of AI, such as language translation tools, enables student learners to learn best within the context of their individual abilities and preferences (Chassignol et al, 2018).

Other authors Holmes et al. group the connections between AI and education (AI&ED) under four headings "Learning with AI", "Using AI to learn about learning", "Learning about AI" and "Preparing for AI" (Holmes et al., 2019). According to Miao & Holmes, the study of AI is related to two dimensions - technological dimension of AI and human (humanitarian) modification of AI (Miao& Holmes (2021). In addition to AI-related techniques, technologies, and applications, preparing for the use of AI includes knowledge that prepares users and all citizens for the possible impacts of AI on their lives. Issues such as the ethics of AI, data bias, invasion of personal space must be understood. This defines the human dimension in AI literacy (Holmes et al., 2022).

To describe the application of AI in education, it is good to first describe and systematize the technical aspects of this technology. Such a system is offered by Yuskovychzhukovska et al. According to the authors they can systemize such as following:

Cognitive services. These are AI products that can perform tasks that previously could only be performed by humans. Examples of cognitive technologies are computer vision, machine learning, natural language processing, language recognition, and robotics. Analysing Microsoft collection of cognitive services, developers group them into the following functional categories:

Category "Vision", which includes AI technologies for image and video content recognition. Examples of such application programming interfaces (APIs) are: Computer Vision, Emotion, Face, Video and Content Moderators.

Category "Speech Recognition" involves understanding and synthesizing oral speech, recognizing people by voice. Examples of such APIs are: Custom Speech, Speaker Recognition and Bing Speech API.

Category "Natural language processing" involves understanding, word processing and "prediction" of what a person expects. Examples of such APIs are: Bing Spell Check, Language Understanding, Linguistic Analysis, Text Analytics, and Web Language Model.

Category "Knowledge" aims to add meaning to the text and combine them with other general meanings and concepts. Examples of such ARIs are: Academic Knowledge, Entity Linking, QnA Maker, and Language Exploration.

Virtual, mixed and Augmented Reality that can radically change education, making learning a more exciting process. Experts in the field of educational technology already predict that in the future inexpensive versions of such technologies will replace textbooks and take the learning process outside the classroom. AI will not only implement these technologies, but also analyse their effectiveness and optimize the benefits they can provide.

Internet of things and peripheral computing. Today, there are more Internet of things devices than humans, and researchers predict that by 2025, the number of such devices will exceed 40 billion (The Growth in Connected IoT Devices, 2019). Educational institutions already use a variety of Application of Artificial Intelligence in Education. Cloud computing may not always meet the required response time requirements. Internet of Things technology often requires high bandwidth, minimal latency, and reliability, which is why peripheral computing is important. This means that there is no need to send data for processing to the cloud storage - data processing is even faster.

Metacognitive scaffolding, which aids the learner only, when necessary, with a gradual reduction or minimization of the intervention of the teacher as the student's competence increases. The use of AI in education allows not only to determine when and in what applicants need help, but also to monitor when to increase or decrease the amount of assistance provided during the educational process. Applicants themselves benefit from the findings of their training; they become the main users of AI technologies and services, not just data subjects.

Personalization and individualization of the educational process. AI is able to implement personalized and individualized learning, allowing obtaining huge amounts of data and formulating conclusions that can be used to develop an educational trajectory that takes into account the individual needs and abilities of students.

AI-assisted learning primarily includes innovative virtual learning and data analysis and prediction. The main scenarios of AI application related to the support of relevant technologies are shown in Table 1. (Chen et al., 2020).

TABLE 1. AI learning scenarios and technologies (Chen et al., 2020)

Scenarios of AI education	Corresponding technology
Assessment of students and schools/universities	Adaptive learning methods and methods for assessment, personalized approach, academic analytics
Grading and evaluation of paper and exams	Image recognition, computer-vision, prediction systems
Personalized intelligent teaching	Data mining, mind map, intelligent teaching system, learning analytics
SMART school	Face recognition, speech recognition, virtual labs, AR, VR, hearing and sensing technologies
Online and mobile remote education	Edge computing, virtual personalized assistants, real-time analysis

Intelligent educational systems provide timely and personalized instruction and feedback for both instructors and learners. They are designed to improve the quality and effectiveness of learning through multiple computing technologies, especially technologies related to machine learning with statistical models and cognitive learning theory (Kahraman et al., 2010).

As an educational model and subsystem of AI, machine learning can be considered, the meaning of which is the discovery of formed knowledge, the process of analysis based on collected data from a sample, which generates models and structures knowledge. For example, machine learning can help create recommendations for students when choosing different disciplines or majors. Also, instructors can understand how a concept is being learned by students. It is especially important when evaluating students in exams. Machine Learning includes techniques such as decision tree creation, inductive logic programming, clustering, Bayesian networks, and more.

According to the assessment of the nature of the application of AI in education and as outlined in the UNESCO report, AI will potentially promote improved access to learning by removing barriers to learning, automating management and administrative functions in academic institutions, and optimizing instruction and learning as well as promoting empirical or evidence-based solutions and initiatives in education. (UNESCO, 2021).

As a virtual platform, it can create a better professional environment for instructors and learners. AI as an assessment tool can be used for assessment and exams and free up the teacher's time. Additionally, it helps students navigate the different content pathways and customize learning according to their strengths and weaknesses.

Table 2. shows the various AI functions that can work in educational scenarios of administration, instruction, and learning. Detailed findings from the application of AI in education are summarized and discussed below.

TABLE 2 The Functions AI Provides in Educational Scenarios (Chen et al., 2020)

	The work Al can do in education
Administration	• Perform the administrative tasks faster that consume much of instructors' time, such as grading exams and providing feedback. • Identify the learning styles and preferences of each of their students, helping them build personalized learning plan. • Assist instructors in decision support and data-driven work. • Give feedback and work with student timely and directly.
Instruction	• Anticipate how well a student exceed expectations in projects and exercises and the odds of dropping out of school. • Analyze the syllabus and course material to propose customized content. • Allow instruction beyond the classroom and into the higher-level education, supporting collaboration. • Tailor teaching method for each student based on their personal data. • Help instructors create personalized learning plans for each student.
Learning	• Uncover learning shortcomings of student and address them early in education. • Customize the university course selection for students. • Predict the career path for each student by gathering studying data • Detect learning state and apply intelligent adaptive intervention to students.

We assume that the use of AI-driven tools can be in the following three directions:

1. Using AI to *support administrative systems* (such as recruiting, scheduling, and training management);
2. Using AI to directly *support teaching* (intelligent preparation of learning materials, intelligent learning systems, dialogue-based learning systems, exploratory learning environments, automatic writing assessment, chatbots, cobots) and AI to support learners with disabilities;
3. Using AI to *support learning*, which is based on a type of automation that involves analyzing data through various analytical techniques. This data is used to track learners' learning progression and how they do so. The goal is to support students in the learning process and to plan its future development.

Using AI for learning also includes looking at *learning AI*. This includes increasing the AI knowledge and skills of learners of all ages (i.e., primary, secondary to tertiary) and their educators, covering AI techniques (e.g., ML) and AI technologies (e.g., Natural Language Processing) and others (Miao & Holmes, 2021).

AI in Educational Administration. One of the areas in education affected by AI is the performance of various administrative tasks in the educational process. Such as assigning tasks to students, reviewing papers, grading student work and providing feedback to students. According to Sharma et al. these administrative functions of AI in education are particularly relevant in distance and online learning, where institutional and administrative services are delivered more efficiently through AI (Sharma et al., 2019).

Specific educational platforms called PMLs have built-in features that facilitate student assessment and feedback for continuous learning improvement. Other programs such as Grammarly, Ecree, PaperRater, and TurnItIn also provide opportunities to perform various administrative functions, including plagiarism checking, grading and grading, and providing feedback to students on areas for improvement. Thus, AI reduces the documentation and workload of educators in the performance of various administrative functions, thereby providing them with conditions to concentrate on teaching - selection of learning resources in accordance with the curriculum, etc. (Sharma et al., 2019). AI has improved efficiency in performing administrative tasks such as reviewing student work, grading and providing feedback on assignments through automation using web-based platforms or computer programs.

Rus et al. posit that intelligent instructional systems (ITS) perform a wide range of functions, including assessing and providing feedback to students on their work (Rus et al., 2013). ITS instructors (such as TurnItIn and Ecree), he says, provide guidance and instruction to help students excel in their studies.

Data mining of the learning process in the application of AI is associated with the generation of systematic and automated learner responses. For example, learner demographics and grade data can be analysed from a small number of written assignments. This it can also be used to predict a student's future performance and warn of the possibility of dropping out, for example. Furthermore, data mining becomes a powerful tool for improving the quality of the learning process, leading to a better understanding of learners' educational settings and even interpersonal relationships.

AI in teaching. Another key area where AI is being seen in education is teaching. AI has made it easier to create and deploy systems that are clearly very powerful pedagogical tools. These tools have fostered an improved quality of learning.

Timms discusses various applications of AI as a pedagogical tool or learning platforms *(MLP)*; simulation-based instruction that involves using various technologies, such as virtual reality, to demonstrate or display concepts to students or hands-on demonstration of materials, providing students with experiential or hands-on learning. He also highlights that another key form of application of AI in education is the development and use of robots as assistants to educators and colleagues (cobots/chatbots) that can be used for advanced learning, such as teaching students to read and pronounce words (Timms, 2016).

Gamification, i.e., the use of educational game applications related to VR and 3-D technologies, can also be considered as a way of applying AI for educational purposes, which brings significant benefits to the quality of learning (Kiesler, et al., 2011, Le et al., 2013). It can be emphasized that *personalized learning* methods can also be combined with gamification techniques to get an even higher quality of education. In particular, gamification elements such as ranking, and points can be useful for recording student progress and solving the problem of balancing students' speed of understanding new academic material.

Computer Assisted Language Learning (CALL), which provides students or learners with personalized instruction, as well as writing and translation assistants in language learning. An example of offering foreign language training is the Duolingo app https://builtin.com/company/ duolingo. It is a free language learning app that incorporates machine learning into its technology to help language learners. Data collected from your answers is fed into Duolingo's statistical model, which predicts how long you'll remember a particular word before needing refresher exercises. As a result, Duolingo knows when to ping you with a suggestion to retry certain tasks. The program also includes game moments that create a sense of competition.

Amazon AWS https://builtin.com/company/amazon-web-services offers free machine learning services and products like Amazon SageMaker to help developers and data scientists build, train and deploy ML models. AWS also offers Amazon Rekognition, which uses machine learning to identify objects, people, text, and activities in both images and videos.

The concept of the application of elements of *Virtual Reality* as an element of AI in education is discussed in other studies. For example, Wartman and Combs highlight the use of AI in the form of virtual reality and simulation in medical education related to conducting surgical operations, anatomy exercises, etc.

The post-pandemic time has also brought a huge development of digital technologies. Advanced technologies, such as AI, ML, neural networks etc. have found their use in various research areas and have been continuously implemented also into curricula at many universities study programs.

Here we can point out some *examples* of the use of advanced technologies at the Faculty of Natural Sciences, UMB. A key role in incorporation of those technologies into educational practice at the faculty is performed by the Department of Computer Science. Students of Applied Informatics gain an understanding of those technologies and are trained to be able to develop applications of advanced technologies for the use in a practice in various areas. For example, as a result of student bachelor thesis a set of applications of virtual reality was developed that were successfully used in the treatment of phobias (Horváthová et al., 2016).

Such student projects usually require an interdisciplinary collaboration with researchers or faculty of the relevant science branch. The applications originally developed for the research purposes are consequently implemented into teaching of the given science topic.

Other applications are being developed directly by academic staff members. As an example, we can mention research of A. Michalikova and M. Vagač (2015). They have developed a method to automatically detect a tire tread in provided image from a given database.

A special attention is given to a development of applications directly useable in education. We will introduce four examples of a such application of advanced technologies within science education at the Faculty of Natural Sciences UMB. Three of them represent the use of machine learning in various branches of chemistry and are used in chemical education. The last one is an example used by students of biology.

Molecular modelling using the machine learning approach. Molecular modelling is a theoretical approach where atomic models of the structures of chemical substances or materials are constructed with the help of computers. Subsequently, selected calculations are carried out for the modelled structures, either electronic-structural based on the Schrodinger equation, or simpler and computationally much faster, based on the principle of interatomic interaction potentials (hereinafter referred to as potentials).

They are the interatomic interaction potentials that open up the space for entry of neural networks. A characteristic feature of the potentials is that they must be parametrized for a specific chemical system, or a set of systems, described by more accurate electron-structure methods, most often by the density functional method. The Department of Chemistry uses a software (see https://www.scm.com/doc/MLPotential/index.html) that can parameterize potentials using the machine learning approach. The potentials generated in this way will also serve in the teaching process within the course Molecular Modelling, which is taught at the Department of Chemistry of UMB (Iliaš, 2022).

An identification of cannabinoids with the help of machine learning. Various ways of an identification of drugs, including new synthetic cannabinoids, form a part of curricula of Forensic and Criminalistic Chemistry study programme. The neural network models were built as a part of diploma thesis that can identify the cannabinoids. The developed neural network can learn from the pictures of a structure of cannabinoids and non-cannabinoids and classifies the substances into those two categories. The input data were taken from Cayman Chemicals database. The neural network has proved to be an effective tool for identifying forbidden substances among huge number of substances that are freely available. For the students of Forensic and Criminalistic Chemistry, the developed neural network also represents a working example how machine learning can be used in their future practice (Kotočová, 2021).

An identification of dangerous situations in chemistry labs. The COVID-19 pandemic required very often so as researchers or students worked in laboratories in isolation from other staff or students. It has caused a lot of problems concerning possible safety risks. In the case of a dangerous situation that could occur in the laboratory nobody could help the student when he/she worked lonely. To minimize the risk of a dangerous situation in the chemistry lab a new application of the machine learning is being developed. It will learn to identify a danger from the face of a student who is in a difficult situation. The system will then "call for help" (Budzák, 2022).

An identification of fungi by using fuzzy interference system. Students of biology develop during their study an understanding of principles of species classification and are trained to apply their general theoretical knowledge to identify unknown kinds of species. The course Diversity and phylogeny of protists, algae and fungi introduces besides traditional approaches of species classification also an application of advanced technologies in this area. Students get familiar with an original method of identifying fungi that was developed in cooperation of researchers from the Department of Computer Science and Department of Biology of the Faculty of Natural Sciences, UMB. The method uses fuzzy interference system of Sugeno type and was successfully tested to determine central European Ganoderma species. (Michalíková, et al., 2021).

Incorporating Augmented Reality is also a tool to impact AI in the teaching and learning process. Next chapter is devoted to this topic.

Pokrivcakova highlights the pedagogical possibilities of integrating AI into computer programs and the development and use of chatbots or online computer-based robots with conversational and dialogic capabilities to answer routine student inquiries and in some cases to distribute learning materials (Pokrivcakova, 2019).

Rus et al. note that intelligent learning systems or ITS equipped with conversational and dialogic capabilities, as well as integrated with animated conversational agents, in the form of chatbots or cobots, have encouraged the realization of effectiveness in teaching.

AI provides improved delivery of course content, starting from the curriculum development phase to the actual delivery of content or instruction, even more so in online and web-based learning platforms. Thus, the correspondence between the curriculum and the specific needs and abilities of the learner ensures the personalization of learning. Programs such as DeepTutor and AutoTutor, as discussed by Rus et al. are learner-centric programs that promote personalization and personalized content according to learner capabilities and needs, thereby enhancing the learner experience and promoting the achievement of learning objectives. Some studies highlight the role of technology in AI to promote academic integrity, use of plagiarism and proctoring checks, and online monitoring of student activities on platforms such as Grammarly, TurnItIn, and White Smoke, among others (Sutton, 2013).

AI in learning. Learning, which is an integral part of education. There are various ways in which AI has been adopted and implemented or used to enhance the quality of learning.

We believe that they relate to the following aspects:

- the customization (of the curricula and content in accordance with the needs and abilities of the learners)
- turning learning into a more engaging and experiential process and stimulating interest in learning (VR, AR, gamification, etc.)
- by providing wider access to training through online and web-based platforms.

AI in education has the potential to improve conditions for independent (personalized) learning. This is done based on learner behaviour data collected during the learning process. This data is then analysed to assess how knowledge has been mastered – resulting in a 'knowledge map'. A relationship can also be established between learning outcomes and various factors that influence it, such as learning resources, structure of learning content, teaching methods, etc. (Nunn et al., 2016). Knowing these maps of learners' knowledge allows trainers (instructors) to adapt their teaching strategies and actions. It is assumed that this would help to offer appropriate assistance to learners in need.

AI offers such assistance based on built-in options based on different *learning models*. The user interface allows learners to present themselves through multiple input media – voice, input, symbols, clicking, and renders the processed results through text, figures, tables, etc. The advanced human-machine interface provides AI-related features such as speech interaction, speech recognition and learner emotion detection.

One of the important applications is that AI based on data mining can achieve personalized learning, where students do their own learning, at their own pace and deciding their own AI-assisted *learning method*. Thus, learners can choose to study what they are interested in, and the instructors adapt the course and the teaching method according to the interests of the students.

Some platforms will encourage the personalization and customization of content and thus encourage the absorption and retention of information, which enhances the learner's learning experience. For example, an app like KNEWTON makes real-time recommendations for students based on deciphered learning style, as added by technology using machine learning algorithms, and subsequently customizes learning materials or content based on learner needs. Other platforms with similar capabilities include CEREGO, Immersive reader and CALL, which together with other platforms have the potential to improve the learning experience of learners at all levels of the education system, from early childhood education to undergraduate and graduate levels. Pokrivcakova also noted that the integration of AI and the use of chatbots also improves the learning experience of students, as they use the machine learning algorithm and deliver content customized to the learning needs and abilities of students.

AI is having a major impact on the learning process through the application and use of *simulation-based learning* and intelligent training systems (ITS). Virtual Reality and simulation promote better student learning and prepare them for the coming new age of widespread application of AI in industry (Mikropoulos & Natsis, 2011).

Other applications of AI to promote learner engagement in the learning process is the use of AIWBES that adapt and generate learning content according to learner needs based on understanding their behaviour and adjust accordingly by generating content appropriate to learner needs, its age, physiology and psychology characteristics and properties. In this way, students receive the most effective and accessible learning that will stimulate research ability and ability to solve everyday problems.

Other benefits of AI and its effect on the quality of learning have been highlighted in other studies that focus on web-based platforms. For example, Kahraman in discussing important principles or components of AIWBES, such as adaptive hypermedia, information filtering, class observation, and collaborative learning, among others, noted that they promote collaboration, interactions, and learning among students (Kahraman et al., 2010).

The impact of AI on learning relates to the use of AI to promote *academic integrity*, improve learning using *review and writing aids* (TurnItIn, Write-to-Learn tools). However, other studies have highlighted the possible harmful or adverse effects of AI on learning. Crowe et al. noted in their study that AI may enable plagiarism and threaten academic integrity as it may facilitate or enable students to use off-the-shelf resources for reports and to generate texts (Crowe et al., 2017).

In the topic of the impact of AI on learning, it is also necessary to touch on the issue of the learning of AI by students, educators and other users. The proposal of Miao & Holmes is that all citizens should also be encouraged and supported to achieve a certain *level of AI literacy*. They must possess the knowledge, skills and values focused on the development, implementation and use of AI technologies. The UNESCO report recommends that the world's citizens understand "what the impact of AI might be, what AI can and cannot do, when AI is useful and when its use should be questioned, and how AI can be managed for the public good' (Miao & Holmes, 2021). Learning AI involves increasing the knowledge and skills of what AI is and how to use it in learners of all ages and their educators. Knowledge of AI techniques (e.g., ML) and AI technologies (e.g., natural language processing) are required, along with statistics and coding (Miao & Holmes, 2021).

AI learning includes the use of:

- AI-driven tools in teaching and learning such as: intelligent learning systems, dialogue-based learning systems, exploratory learning environments, automatic writing assessment, cobots and chatbots, supporting learners with disabilities;
- AI for training administration such as recruitment, scheduling and training management;
- AI to directly support educators.

Some scholars talk about learning about AI as two kinds of *AI literacy*—one with a *technical dimension* and one with a *human dimension* (Holmes et al., 2022). Preparing to use AI includes understanding the potential impact of AI on users' lives. They need to understand issues around the ethics of using AI, workplace surveillance, data bias, and more, of ensuring that all citizens are prepared for the possible impacts of AI on their lives – helping them to look beyond the noise to understand issues such as AI ethics, data bias, surveillance and the potential impact on jobs. This preparation is called preparation for AI literacy with a *human dimension* (Holmes et al., 2022).

In the past three decades, most scientific research and applications of AIED have focused on what should be the learning accompanied by the AI, which is in the direction of *automating the teaching activity*, because the learners learn independently of the teacher or have their own instructor (assistant) in the person of AI. This is more about adapting pedagogic approaches and focusing on automating pedagogic practice rather than innovation – for example examination observations rather than using innovative ways of assessment. This AI feature having a direct impact on helping learners in areas where there are few experienced or qualified educators, such as rural areas in developing countries, can be very useful. The question that can be raised here, in the context of AI as aiding learners, is that of *trust*. For AI tools to become more widely used in classrooms and classrooms, it must be believed that AI is an educationally useful technology and learning will improve without harm.

AI literacy cannot be limited to its technological components. AI literacy should include both the technological and human dimensions of AI, both how it works (techniques and technologies) and what its impact is on humans (on human cognition, privacy, agency, etc.) (Holmes et al 2019).

Advantages and disadvantages of using AI in education. Some advantages and disadvantages of using artificial intelligence technologies for participants in the educational process can be summarized as follows:

AI creates the conditions for personalization and individualization of training. Intelligent learning systems create a digital profile of a student that, used by the teacher, has the potential to result in the learning process.

A personalized learning environment not only improves the quality of the educational process, but also enables students with health problems to learn more effectively.

AI provides students with hands-on or experiential learning experiences, especially when used in conjunction with other technologies, such as virtual reality, 3-D, gaming, and simulation, thereby enhancing student learning experiences.

A well-chosen AI system can shape students' imagination and creativity by analysing their learning style and emotional state and initiative to improve learning ability and creativity and stimulate subjective initiative.

Personalized learning also has some criticisms. Kohn, an American author and speaker in the fields of education, writes "…meaningful (and truly personal) learning never requires technology. Therefore, since personalization is presented from the outset as software or screen related, we must be extremely sceptical about who really benefits" (Kohn, 2015).

All other criticisms basically refer to the idea that a highly motivated student doesn't even need a personalized learning system because that student discovers all the important information that is needed for his learning on his own. There is an opinion that the popularity of the term personalized learning nowadays does not come from the demands of students, but from companies that want to sell software (Chassignol et al. 2018).

The intelligent educational environment becomes a promising means of self-learning for students. The implementation of AI technology provides many opportunities for the development of massive open online courses (MOOCs).

The COVID-19 pandemic, quarantine, restrictive measures and mass transfer of students to distance learning in almost all countries of the world have only updated even more the *trend:* An intellectual educational environment to be become promising not only in distance learning, but also in self-education, including lifelong learning.

The application of AI stimulates the continuous improvement of the *digital competence of trainers*. They must know the possibilities offered by AI for automating a number of activities, know how to apply various electronic educational tools and applications and make full use of the electronic learning platforms (MLP). This will increase their pedagogical functionality and improve the quality of the learning process.

AI enables getting the most out of *data analysis*. Since data plays a much more important role today than ever before, its use can provide a competitive advantage to educational institutions.

AI enables the automation of repetitive learning and search processes by leveraging data. AI can automate basic actions in education, such as the certification. Automating assessment processes, for example, can help trainers use their time more efficiently and focus on collaboration and professional development.

Assessment of many assignments, detection of learning and teaching gaps is not a problem with the implementation of intelligent systems. In addition, the measurement of learning progress is becoming more popular and more effective. Sometimes it is possible that these smart scoring systems miss some correct ones because the system decides based on *massive statistics*. This means that AI-based evaluation systems cannot be absolutely correct in every possible situation without a human mentor.

AIED collects data representing learners' responses to questions, their mood and emotional state (for example interested or distracted), what they click, and how they move their mouse across the screen (Chassignol et al. 2018). A single session with a child interacting with an AI or other e-learning system (such as a MOOC or serious game) can generate "about 5-10 million data points on student action each day." This data is known as a learner's *digital footprint* and can be used to search and act on patterns of learner participation in a class, approve or deny learner places in institutions, and identify patterns of participation (Pardo et al. 2019).

Questions of social and ethical importance can immediately be raised: who has the right to collect these digital traces, how are they transformed into useful knowledge, how can and how is this knowledge used, who has access to it and who uses this knowledge and who benefits from them? The answers leave us wondering if this data will improve training or benefit AIED vendors and serve business intelligence.

AI-based programs are a source of *feedback* for both the learner and the teacher. AI systems have successfully proven themselves in online learning that they can monitor student performance and promptly alert instructor to existing performance issues. Such AI systems create conditions for effective improvement of the educational process by timely introduction of relevant changes.

AI tools are believed to be able to automate the assessment of learner knowledge, providing greater objectivity and freeing up time for trainers. It raises the question of whether AI is capable of deeply interpreting or accurately analysing the way a teacher can. Therefore, the understanding that the teacher does the assessment, and the AI only supports this process is more realistic. There is little evidence for the claim that AI can save teacher's time.

Heads of educational institutions with the help of AI technologies can more effectively manage and guide the processes of change in the institution. AI programs help students choose majors based on the areas in which they excel. Intelligent systems can change the way information is sought and used by educational institutions and academia.

Another focus of AI in supporting institutions is the use of chatbots to facilitate communication with learners and to provide 24/7 self-service (Leslie et al., 2021).

Institutions are also investing in analytics tools to predict *student dropout*. An example of such an application of AI is the Course Signals system at Purdue

University, which initially appeared to have a positive impact on learner retention, but this was followed by controversial discussions about the results. Using AI to predict dropouts is also a popular area of research, especially in MOOCs (massive open online courses), where dropout rates can reach more than 90%. The goal is to understand the factors that may influence dropout. There is currently little evidence of the effectiveness of such systems.

An objective examination of the actual effects of AI on administration, teaching and learning requires pointing out some shortcomings/imperfections and challenges of AI (Yuskovychzhukovska et al., 2022)

In 2019, the Committee of Ministers of the Council of Europe adopted a recommendation on education for digital citizenship, in which a key focus was the application of artificial intelligence (AI) in an educational context:

"AI, like any other tool, offers many opportunities, but it also brings with it many threats, which make it necessary to take into account the principles of human rights in the early design of its application. Educators need to be aware of strengths and weaknesses of AI in learning so that they are empowered – not overpowered – by technology in their digital citizenship educational practices. AI, through machine learning and deep learning, can enrich education... Similarly, developments in AI can profoundly affect interactions between educators and learners and between citizens in general, which may undermine the very essence of education, and namely the promotion of free will and independence and critical thinking through learning opportunities…"

Although wider use of AI in learning environments seems premature, education professionals need to be aware of AI and the **ethical challenges** it poses in the context of learning (Council of Europe, 2019).

Globally, AI in education is often met with enthusiasm – with many international reports and articles strongly recommending its use. However, it should not be underestimated that the use of AI cuts across the focus of the Council of Europe directorates on data protection, children's rights and competences for a democratic culture.

The Council of Europe's Ad Hoc Committee on Artificial Intelligence (CAHAI) was tasked with exploring the potential of AI based on broad multi-stakeholder consultation, based on the Council of Europe's standards on human rights, democracy and the rule of law. CAHAI has now been replaced by the

Committee on Artificial Intelligence (CAI), which aims to identify issues and improve the relationship between AI and education.

Indeed, recent work (e.g., Centre for Data Ethics and Innovation 2020; (Tuomi, 2018)) highlights the technical, social, scientific and conceptual limitations of AI in education systems and notes the lack of robust independent evidence of its efficacy or success in achieving of the planned results.

Although AI brings several benefits to education, it will also face some **challenges**.

- *First* of all, it is necessary to ensure fairness in the application of AI in education. With the development of AI, developing countries face the risk of being left behind in the development of education due to their technological backwardness and limited access to the Internet. In addition, most AI algorithms come from developed countries, they do not fully consider the conditions of developing countries and cannot be applied directly.
- *Second,* attention must be paid to the ethical and safety issues arising from the collection, use, and dissemination of data. The application of AI has raised many ethical questions regarding the provision of personalized advice to students, the collection of personal data, data privacy and ownership of responsibilities and data submission algorithms.
- *Third*, Educators need to master new digital teaching skills to use AI appropriately. In addition, AI learning product developers need to understand how faculty work and create a product that is applicable to learning.
- *Fourth*, AI is changing the style of learning by placing higher demands on students' autonomy and their ability to learn independently. This changes the learning objectives and they will be increasingly linked to the formation of independent learning skills.
- *Fifth*, more attention should be paid to communication between students. With the more active use of AI learning platforms, students communicate

with machines as a priority, which deepens social communication skills. To solve this problem, AI education projects should create a distance learning model that emphasizes socialization (Saleh, 2021).

It is therefore implied, and as inferred from the analysis, that AI has significantly affected or had a major impact on the education sector in general and, in particular, in its application in specific educational institutions.

After reviewing the characteristics and possibilities of AI to influence education, we can summarize that although there are no significant differences with traditional education, the application of AI brings significant changes, although it will not completely replace traditional education. AI is added and adapted to the traditional learning process, as was done with gamification and is currently happening with VR and AR technologies. Understanding the problems that may arise when implementing AI in education will help people better prepare and improve the future application of AI in education.

With the profound development of economic and technological globalization, the important role of AI technology in education is becoming more and more prominent. And many countries regard the development of AI technology as a national priority. The main characteristic of the innovative AI-based educational ecosystem is the precision, individualization and adaptation of educational services and management. In the process of building an innovative educational ecosystem, schools, teachers and students face various challenges and problems posed by AI. To solve these problems and realize the perfect connection between AI technology and education, teachers, students and other members of educational systems must work together.

This work contributes to existing knowledge in the field and will be of interest to technology-enhanced learning professionals, educators, students, and people interested in the state of our education.

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1.2. "Augmented reality" technology in education (Diana Stoyanova)

Definition of the term "augmented reality"

The term "Augmented reality" (AR) was first introduced in the first half of the 1990s. by Thomas Caudell, who was then one of the leading engineers of the Boeing Company (Lee, 2012). The first definition of augmented reality was given in 1994 by Milgram and his associates (Milgram, et al., 1994). They offer a definition of virtual and augmented reality in the context of a continuum (Fig. 1.1). At the left end of the continuum is the real environment, and at the right is the virtual, which is a completely unreal, entirely computer-generated environment. Between these two poles lies the so-called "mixed reality" (a part of which is also the "augmented reality"), where we have a mixture of virtual and real objects. When moving from left to right along a continuous line, the virtual images increase and the connection with reality decreases (Wheeler & Ivanova, 2010).

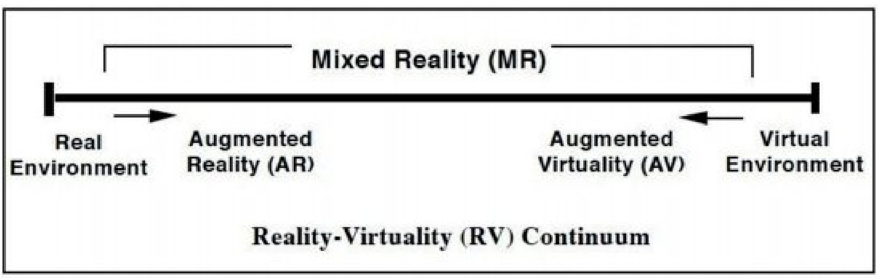

Fig. 1.1. Miligram and Kishino's Reality-Virtuality Continuum (Milgram, et al., 1994)

In 1997 Azuma gives one of the most widely accepted definitions, according to which the technology "augmented reality" is the superimposition of computer-generated 3D objects on a real environment (Azuma, 1997). Any AR system should have the following basic characteristics:

1. Combines virtual and real objects.
2. Offers real-time interactivity.
3. Provides real-time spatial alignment (positioning and orientation) of virtual objects relative to the real environment.

Although this definition implies the "extension" of only one of the human senses - vision, "augmented reality" technology can be applied to different senses (to complement what we see, hear, etc.) (Carmigniani & Furht, 2011).

AR systems can assist or replace missing senses, such as "assisting" the vision of blind users by using additional audio information, or "assisting" the hearing of deaf users by using additional visual images.

Many researchers and educators believe that the term "augmented reality" should not be defined too restrictively. Limiting it to a particular type of sense or imaging technology may limit its future development (Wu et al., 2013). Therefore, based on the already mentioned definitions of Milgram and Azuma, they propose new definitions that are broader in meaning.

According to Klopfer (Klopfer, 2008), an AR system is any system that combines real and virtual information in a meaningful way. This information can be: text, images, video, sound, 3D objects, animation (Bower et al., 2014). In this case, AR creates additional sensations in the user, a better perception of the environment (Graham et al., 2013; Azuma et al., 2001).

An even broader definition is provided by Zhou et al. (Zhou et al., 2008), according to which AR technology allows real-time objects to be overlaid with computer-generated virtual images.

Taking into account the above definitions, we can give the following definition of augmented reality: superimposition of context-dependent virtual content (text, animation, graphics, video, 3D objects) on real objects. The image generated by augmented reality software is a combination of the real environment that the user sees and a computer-generated virtual scene that alters our perception of the reality and provides additional information.

Hardware components used to create augmented reality

The main hardware components needed to create augmented reality are: processor, visualization system and sensors.

Visualization system

Through the visualization system, the user sees the real and virtual objects in a unified whole. These include - helmets for augmented reality, screens of personal computers or mobile devices, video projectors.

Head-mounted display (HMD). A head-mounted display is a device worn on the head that simultaneously positions images from the real and virtual worlds in front of the user's eyes (Fig. 1.2). The market also offers models that stimulate not only vision and hearing, but another human sense - the sense of smell. Users can smell different aromas, which "immerse" them in a completely new way in augmented reality (Coward, 2015).

Fig. 1.2. Real object observed with HMD
(https://www.hexaengineers.us/the-revolution-that-augmented-reality-is-bringing-to-industry-4-0/)

A variety of HMD are the "smart" glasses. Google Glass is one of the first such devices, introduced in 2012. On one side of the glasses is a small retinal display (Fig. 1.3). It projects text and images directly into the wearer's peripheral vision, allowing them to maintain additional contact with what they are actually seeing. The glasses are connected directly to a smartphone equipped with augmented reality software, acceleration and direction sensors, which make it possible to understand where the gaze is directed and provide additional information about the observed object ("Google Glass", 2016).

The main criticism of Google Glass is that it violates privacy when used in a public place because the device can record the conversation between people without their consent.

In 2022, Google presented the prototype of its new glasses for augmented reality. The test glasses will have several specific features to try out in real situations. These include using them for real-time language translation, conversation transcription, visual search and navigation. This information will be displayed on the glasses themselves and superimposed on the real objects. For now, however, the glasses themselves will not be able to take photos and video, which was the subject of criticism for the company's first glasses - Google Glass (Antonov, 2022).

Fig. 1.3. Glasses with augmented reality Google Glass
(https://technews.bg/article-83413.html)

Screen. A computer monitor or mobile device display can be used as a screen for viewing the image generated by the augmented reality software. It's a much cheaper option than HMD devices, and it also allows augmented reality to be viewed by multiple users at the same time.

Video projector. Here, augmented reality is created by visualizing graphic information directly on real objects.

Sensors. The main role of the sensors is to collect information from the surrounding environment and transmit it to the augmented reality software. The purpose of some sensors is to provide information about the user's location and orientation. These are: digital cameras, GPS, accelerometers, etc. Other sensors collect information about the surrounding environment such as illumination, pressure, temperature, etc. These include: light sensors, barometer, thermometer, etc. (Craig, 2013).

Processors. Augmented reality systems require powerful processors that, in real time, can:

- process the information received from the sensors;
- provide spatial alignment (positioning and orientation) of virtual objects relative to the real environment.

Types of augmented reality

There are several main types of augmented reality (Types of Augmented Reality applications):

Marker-based augmented reality. In the marker approach, augmented reality is created after recognizing a so-called marker. Most often, these are square blackand-white images, similar to a 2D/QR barcode, marking a specific location or real object from the environment. After the augmented reality software reads the tag, the user can see the virtual content associated with it (Fig. 1.4). Currently, this approach is more widespread and easier to implement.

Fig. 1.4. Marker-based Augmented Reality
(https://medium.com/@codefluegel/5-business-use-cases-for-augmented-reality-a30e19fcd69d)

Architecture of an AR system based on marker recognition is shown in Fig. 1.5.

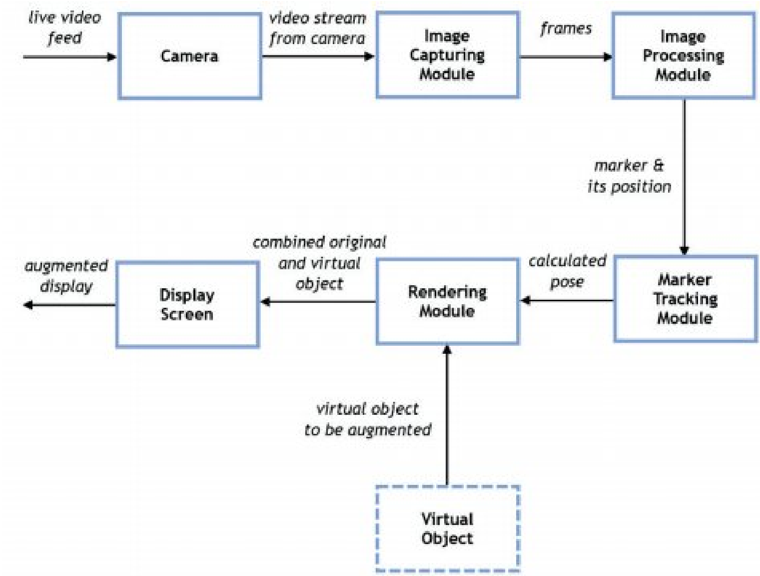

Fig. 1.5. The architecture of an augmented reality system based on marker recognition (Birje, 2013)

The main components of such a system are (Birje, 2013):

1. Camera
2. Image capturing module
3. Image processing module
4. Marker tracking module
5. Visualization module

The real-time video captured by the camera is transmitted to the image capturing module. This module analyses each frame of the video and converts it into a digital image. Digital images are given to the image processing module where they are analysed for AR marker detection. Detecting this marker is important to determine the position where the virtual object will be superimposed. As soon as it is detected, its position is transmitted to the marker tracking module. This module in real-time calculates the user's perspective i.e. the position and orientation of the camera relative to the marker. These coordinates are given to the visualization module, which combines the real image from the camera with the virtual components and visualizes the augmented reality on the display.

Location-based augmented reality. Here, AR is created after processing information about the use's position, detected by location sensors - GPS, digital compass, etc. (Ortman & Swedlund, 2012). Depending on the location, context-dependent information is visualized (Fig. 1.6). If the user changes his location or changes the position or orientation of the device, the virtual content changes according to his new location. AR applications using this approach are most commonly used as virtual guides.

Fig. 1.6. Augmented reality based on geolocation
(https://blog.vakoms.com/everything-you-need-to-knowto-build-location-based-ar-app/)

Projection-based augmented reality. Projection-based AR uses projectors to overlay virtual content directly onto real-world objects using projection mapping techniques. This allows users to view AR content with the naked eye without the need for glasses, augmented reality helmets or mobile device screens. The most popular example of this type of AR is the so-called augmented reality sandbox (Fig. 1.7). The sandbox simulates a map in a real-time to allow users to create topography models by moving and shaping real sand. Even virtual water can be "poured" onto the sandbox. In real time, with the help of a simple bucket and spade, the user can "change" the landscape, creating mountains, valleys, lakes and rivers for water to flow.

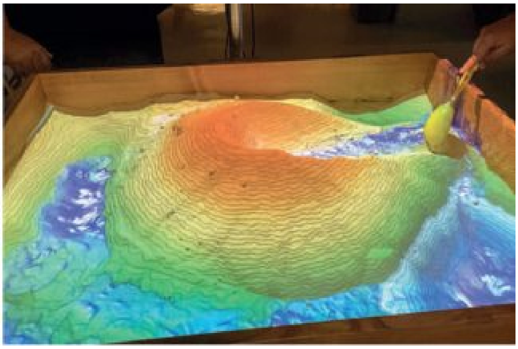

Fig. 1.7. Projection augmented reality
(https://dakotastudent.com/8748/arts-comm/augmented-reality-sandbox-puts-geography-on-the-map/)

Superimposition Augmented Reality. As the name suggests, superimposition AR replaces the image of the real object with digital content on the display (Fig. 1.8). The most popular app based on this type of augmented reality is IKEA Place, which uses augmented reality to show how the IKEA's furniture will look in your home (Lunden, 2017).

Fig. 1.8. Overlay-based Augmented Reality
(https://www.architectmagazine.com/technology/ikea-launches-augmented-reality-application)

Software packages for the development of augmented reality applications:

Vuforia Engine. Vuforia Engine (https://developer.vuforia.com/) is an augmented reality software package that is preferred by over half a million registered developers worldwide. It uses precise and efficient computer vision technology that enables recognition of: square AR markers, 3D objects (cylinders, cubes), English words, photos, etc.

ARToolkit. Key features of ARToolkit (http://www.artoolkit.org/) include:

- recognition of AR markers in video frames;
- determining the geometry of the marker (its position and angle);
- determining the user's point of view by calculating the real position and orientation of the camera relative to the marker;
- generation of augmented reality by superimposing virtual objects on the real image captured by a camera.

Wikitude. The Wikitude AR SDK (https://www.wikitude.com/) enables the creation of applications using a marker and markerless approach to create augmented reality. Main characteristics of this software are the following:

- Ability to create augmented reality depending on the user's current location;
- Stable tracking system based on pattern recognition;
- Enables the recognition of nearly 1000 images;
- Fast and reliable online image recognition**.**

ARmedia3D. The main advantage of ARmedia3D is the ability to recognize not only planar images, but also real 3D objects, regardless of their size and geometry (http://www.armedia.it/). It is designed for Android and iOS mobile operating systems.

Google ARCore. ARCore (https://developers.google.com/ar) uses three key capabilities to integrate virtual content with the real world seen through your phone's camera:

- *Motion tracking* - ARCore can determine the position and orientation of your mobile device;
- *Environmental recognition* – recognizes the size and location of all types of surfaces;
- *Light estimation* - enables your phone to estimate the ambient light.

Apple ARKit. Apple ARKit (https://developer.apple.com/augmented-reality/) is the alternative to Google ARCore. It has the same capabilities as ARCore, but if the two platforms have to be compared, it can be noted that ARKit is better for image recognition, while ARCore is better for general manipulation of graphics and games.

Use of AR technology with mobile devices in the learning process

Until recently, augmented reality applications were mainly available for powerful personal computers. This made the technology significantly more expensive and hindered its widespread use. The rapid development of mobile communications in recent years has radically changed the situation. In terms of functionality and performance, modern mobile devices (smartphones, tablets, PDAs) are increasingly approaching stationary computers. Their low price, their powerful processors, the presence of a camera, GPS, accelerometer, gyroscope, etc. sensors, make these devices highly suitable for creating augmented reality applications (Cvetanovski et al., 2015). The use of this type of application in the learning process inherits the advantages, disadvantages and features of the technologies it combines: mobile technologies and AR technology.

Use of AR technology in the learning process

Advantages:

Several researchers recognize the enormous potential that augmented reality technology has for educational purposes. According to Nunez et al. (2008) AR technology can make learning material more attractive and fun, which is essential to achieve maximum effectiveness of the learning process. Combining real and virtual objects helps to reduce the complexity of the learning material, contributes to its better perception (Shirazi & Behzadan, 2013; Behzadan & Kamat, 2012), and stimulates the imagination and creativity of students (Yuen et al., 2011; Zünd et al., 2015). It can facilitate the understanding of complex abstract and spatial concepts by making them clearer and understandable (Kaufmann & Schmalstieg, 2003; Kaufmann et al., 2005, Dori & Belcher, 2005). Augmented reality allows students to manipulate digital resources, which further stimulates their interest (Wu et al., 2013; Lim & Jung, 2014). Using it in the learning process increases student motivation and activity in class (Di Serio et al., 2012; Li et al., 2014). Experiments have shown that learning material presented with AR technology is suitable for different learning styles (Yuen, et al., 2011; Megahed, 2014). This helps students learn more effectively and increases the durability of acquired knowledge (Di Serio et al., 2012; Solak & Cakır, 2015).

Combining augmented reality technology with mobile devices provides some additional benefits that make it particularly valuable for educational purposes. First, it facilitates access to digital learning resources. Students have access to context-sensitive information anytime, anywhere - outside the school, outside the computer labs. Second, opportunities for collaboration both among students and between students and educators are expanded (Billinghurst, 2003; Vassigh et al., 2014). Third, it does not require students to have prior training on how to work with these devices, as they have already used them in their daily lives.

Disadvantages:

The most frequently cited problem related to the use of augmented reality technology in the educational process is the danger of cognitive overload for students (Dunleavy & Dede, 2014; O'Shea et al., 2009). They have to perform many and different activities related to using AR software and viewing digital resources while simultaneously analysing, making inferences or making decisions as a team (Perry et al., 2008). Managing and controlling cognitive load is of prime importance for the successful application of AR technology in the learning process.

Another often cited problem is the unsuitability of the existing educational system for using AR technology. It should be considered that lessons based on this technology require more time for teacher preparation and are more difficult to lead than traditional ones (Dunleavy, & Dede, 2014) and that children need time to accustomed to using the new technology. All this can lead to some disruption of the educational distribution. Therefore, the successful implementation of such lessons largely depends on the teacher's skills, confidence and willingness to use new technologies (Perry et al., 2008).

Often, the use of mobile augmented reality applications based on geolocation is accompanied by errors and problems arising from the inaccuracies of GPS systems (Bonsor, n.d.). GPS systems have a positioning accuracy of up to 10m and are also not suitable for indoor navigation ("Global Positioning System", 2015). Errors can also occur with AR software using pattern recognition - for example due to low lighting, poor marker quality, etc. (Rabbi et al., 2013). All this can prevent the normal course of the learning process, cause negative emotions in students, thereby reducing the effect of using the AR technology.

The use of this technology in education is associated with additional costs that the school must incur for the purchase of AR software and technical devices (mobile devices, augmented reality glasses, cameras, etc.), for the development of digital learning resources, for the maintenance of Wi-Fi network in the school and others. In the absence of clear positive results, some administrators believe that these costs are completely unjustified.

Main directions for using AR technology in education

The following main directions for the use of augmented reality technology in education can be distinguished (Yuen et al., 2011): augmented reality books, games, applications based on discovery learning, 3D object modelling, learning applications aimed at acquisition of certain skills.

Books with AR. Although they appeared on the market relatively recently, books with augmented reality have gained a lot of popularity. At first glance, these books are no different from the others, but when we put them in front of the webcam or the camera of the mobile device, things change. Through 3D graphics, video or sound, the images from these books literally come alive. Some of the books require the installation of special software, while others require the use of AR glasses (Specht, 2011). The use of augmented reality books in the learning process is one possibility to tailor the learning content to the different learning styles of the students ("Augmented Books", n.d.). They stimulate children's imagination, increase their interest in learning content and make learning an interactive experience (Tomi & Rambli, 2013).

Games with AR. Games is a commonly used learning method, especially among elementary school students. It develops their ability to work in a team, helps them in the process of acquiring knowledge. In this age group, it is especially important to develop thinking to the level of understanding cause and effect relationships. Research shows that games using augmented reality reveal these connections in a more understandable and meaningful way (Horoky, 2010).

Applications based on discovery learning. Learning through discovery is a modern pedagogical approach that is applied with the aim of provoking students' interest in the subject by conducting research activities. Jerome Bruner, considered the main ideologist of learning through discovery, claims that in this way students make sense of the activity while performing it, and not just copy a given action (Emilov, 2015). One of the most popular AR applications based on discovery learning are so-called virtual guides. Visitors to museums, galleries and historical sites, using this type of application, can receive additional information about the currently viewed object in the form of text, audio, video or graphic files (Persefoni & Tsinakos, 2015).

Modeling 3D objects. AR technology can be used to model 3D objects. Models can be moved, rotated, reduced or enlarged, thus allowing the user to view these objects from a different angle (Ko et al., 2011).

Educational applications aimed at acquiring certain skills. With the help of AR technology, context-dependent learning aimed at acquiring a certain skill can be provided (Raheja, 2014). The areas where this type of training application has the greatest potential are medicine and the military. The Army is a leader in using AR for training purposes. Video helmets and smart glasses are a widely used aid in training war games or troubleshooting. In the field of medicine, AR is used to train students and medical staff to perform various medical procedures or surgical operations (Botden, 2009).

AR technology can be successfully used in the education of engineering students. For example, 3D models visualized with the help of marker-based AR can be used when studying the device and the principle of operation of complex machines. Images from the textbooks can be used as markers.

In the conditions of the pandemic time, a rare opportunity was provided to modernize education through the implementation of modern educational technologies, including augmented reality. This will undoubtedly remain a feature of the post-pandemic period in education systems. While many virtual apps and resources were not in high demand before the pandemic, they have become more popular since. In order to use these technologies and tools, it is necessary for faculty and students to gain knowledge about them and develop the skills to use them.

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1.3. Remote laboratories (Janka Raganova, Miriam Spodniakova Pfefferova, Martin Hruska, Zhelyazka Raykova)

Remote experiments represent a relatively new method of experimentation that can be used especially in science education where experimentation plays a decisive role. The method is based on the use of computer-based e-laboratories accessible to any user with the connection to the Internet, equipped with simple technical means (Shauer et al., 2018). Thus, this method has strong global feature.

Remote lab, by definition (Chen et al., 2022), is an experiment which is conducted and controlled remotely through the Internet. The experiments use real components or instrumentation at a different location from where they are being controlled or conducted. The use of remote experiments at university science education is in line with an effort to educate students using strategies compatible to the present state of the society. One of those strategies is the method of e-LTR (e-learning, e-teaching and e-research) (Thomsen et al., 2005). The main features of this method are observations, search for proper information, its processing and storing, organization and planning of work, data and results presentation, etc. Many real remote e-laboratories across the Internet have been published that provide experiments on real world objects, supplying the client with the view of the experiment, interactive environment for the experiment control and resulting data for evaluation (Schauer, 2018).

As a working example we can introduce remote labs that have been developed in the Faculty of Mathematics and Physics UK in Prague, Czech Republic since year 2002. Lustig, Shauer et al. has developed a remote laboratory system with data transfer using Internet School Experimental System (ISES) as hardware and ISES WEB Control kit as software. At the beginning (in 2005) they set up and operated seven experiments, running round the clock, with more than 12 000 connections in three years (Schauer, 2018). Their aim was to draw students more into practical experimental work and to remove the barriers for the possibility for independent laboratory work. They also intended to address positively several issues connected with laboratory work in science, technical or engineering education. For example, the remote experiments enable students to choose optimal for them time and work at their most suitable speed. The access to the costly and potentially safety risk experiments is feasible.

From pedagogical point of view, remote experiments are considered as an appropriate tool to substitute traditional experiments with research laboratories, which enable development of understanding of experimental process (Schauer, 2018).

The first generation of remote experiments was built on Java applets (iSES, 2022). Since 2013 the developers of remote experiments been moving to JavaScript. Up to now the Lustig's team has built 18 remote experiments on secondary school and university level, which are freely offered for the use in school projects, education and also in free time activities (Lustig et al., 2018).

How the remote experiment works?

According Lustig (2018) the remote experiment is an application of the type server-client. On the server side, there is a computer with an experiment, on the client side, there is only a device with the latest version of Internet browser, in which script language is supported.

Server side of the experiment consists of computer connected to the Internet. There is a measuring apparatus connected to the computer (e.g. system ISES, LabVIEW, or other measuring system). It can also consist of stepper motors, controllable sources, multimeters and others. Naturally there is also a real experiment. Systems with analogue or digital control channels, such as ISES, LabVIEW and others, allow building remote experiments of type "control". Special applications must run on the server. Firstly, it is a MeasureServer – a special server application which communicates with hardware from measuring apparatus, e.g. with ISES sensors. Secondly, a WEB server is necessary. It enables to run custom webpages written in HTML with use of JavaScript widgets from the new kit "iSES Remote Lab SDK" developed by Lustig and his team. If online camera view on the experiment is wished, it is necessary to run ImageServer (part of "iSES Remote Lab SDK"), which streams the view of the experiment with fast sensing images (Lustig et al., 2018).

Experience with the use of remote experiments

If the remote laboratories are properly designed, they can according to Nedice (2013) offer students:

- a tele-presence in the laboratory,
- to perform experiments on real equipment,
- to collaborate,
- to learn by trial and error,

- to perform analysis on real experimental data,
- but also, a flexibility in choosing time and place for performing experiments.

The study of Alkhaldi et al (2016) suggests that remote laboratories provide a number of advantages such as remote 24 /7 access, flexibility and freedom to learn at one's own pace and reset/ retrial experiments without wasting resources in a safe environment and provide new opportunities for learning. They have observed that these labs when incorporated with sound pedagogical framework, learner support, and content and tutor interaction result in higher learning outcomes and richer learning experience.

Harward et al. (2008) stress upon cost-effectiveness of remote labs when compared with physical labs. This is one of the greatest advantages for developing remote labs as expensive equipment can be shared by many learners remotely.

Lustigova and Novotna (2013) found that students in remote laboratories greatly improved their data processing skills. Working on their own computers and undisrupted by co-workers and the unknown laboratory territory, they focused on the problem and reached significantly better results. Thanks to fast graphical visualisation and to the great potential of remote labs to recollect data and re-run experiments under many different settings, they also improved their conceptual.

What are the methods used by faculty to teach STEM practical work in remote classrooms?

The increased use of educational technology creates a gap in the use of long-standing pedagogical theories about e-learning. Siemens (2004) claims that the theories of behaviorism, cognitivism and constructivism cannot fully explain technology-assisted learning and this is the reason to propose a new theory - connectivism. One of the weaknesses of the theories of behaviourism, cognitivism and constructivism in explaining e-learning as argued by Siemens (2004) is the notion that learning primarily occurs in the human mind. Through connectivism theory, Siemens (2004) opined that non-human devices have the ability to learn and acquire knowledge. Connectivism attempts to explain learning that occurs in communities formed by learners and devices connected to each other through new technologies.

One of the technologies that enables people and things to form learning communities is IoT (Internet of Things). IoT is described as a network of digital devices embedded in the Internet, thereby enabling communication between people. Connectivism, however, has been criticized for being a "new theory".

It is believed to be based entirely on existing theories, and the claim that new SMART technologies can be learned remains controversial (*Goldie, 2016*).

Another widely used theory in studies seeking to understand online learning is the Community of Inquiry (CoI) framework by *Garrison et al. (2000)*. The CoI consists of three components that correspond to types of presence in online classrooms. These are instructional presence (how online instruction is designed to support cognitive presence and social presence), cognitive presence (how learners make meaning in online classrooms), and social presence (the sense people have of being in a social environment or part of group).The three types of presence are used by researchers as a framework for examining how online learning is experienced.

Nagel and Kotzé (2010) found in their study that the three components of CoI can be measured and are related to teaching quality.

Teaching presence is believed to have a greater impact on how one learns. Teaching through cognitive and social attendance strongly influences the training methods that are used (DeNoyelles et al., 2014). Other scholars such as Anderson (2011) believe that CoI is only one component in an e-learning environment.

As **methods** that are used when working with remote laboratories, the following can be mentioned:

- Practical work in a virtual environment and in an environment with augmented reality
- Experimental work in remote laboratories
- Homework
- Use of educational robotics
- Project-based learning
- Inquiry based learning
- Problem-based learning

What are the prospects in using remote access to laboratories for conducting practical work with students?

Following the experiences gained during the pandemic in experimental work with remote access laboratories, Chu et al. (2021) suggest using allows mobile learning (learning via mobile devices) as a possible alternative. The experiments that have been done by this collective are related to the use of smartphones by students to conduct experiments on the topic of sound, but in virtual laboratories.

In the future, the focus of research may be on the use of phones to receive instructions and collect experimental data from real experiments in remote access laboratories. The applications for working in laboratories with remote access are being improved more and more, which make it possible to work with more diverse experimental tasks from different fields of science.

The lack of sufficient pedagogical research on the effectiveness and specifics of organizing learning in remote access laboratories is the reason why more and more researchers are turning their attention to studies on this topic.

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1.4. Hybrid and blended learning (Zhelyazka Raykova)

There is more and more talk about the two types of training and having in mind that they are becoming a trend, it is very important to understand the difference between them.

What are the **definitions of these two types of learning**?

- Hybrid learning is an educational approach in which some of the learners participate in the learning process in person and online. Lecturers or instructors, or facilitators teach both remotely and face-to-face at the same time using technology such as video conferencing.
- In blended learning, trainers combine face-to-face learning with online activities. Learners complete some components online and others in person.

Both types of learning combine face-to-face and online learning but differ in the scenario by which they do it. In hybrid learning, those who learn face-to-face are different from those who learn online. In blended learning, the learners are the same who study both blended and online. In hybrid learning, the group of learners has a heterogeneous nature - some study in person, others online. In blended learning, learners are not differentiated - they all learn in the same way both online and through face-to-face activities. According to some scientist, hybrid is parallel learning and blended sequential.

Examples 1: Before discussing a problem related to the use of a certain sensor to measure air pollution, students are asked to watch a video that is related to this problem. This is an example of blended learning.

Example 2: The teacher consults on the conduct of an exam in a certain discipline. A part of the students is in the seminar room, and the others have sent or are currently sending the questions to the teacher via chat/video link. This is an example of hybrid learning.

It is not possible to comment on which of the two training approaches is better. Both have limitations and advantages.

Some limitations of hybrid versus blended learning:

Hybrid learning is more difficult to implement because the teacher must divide his attention between two groups that have potentially conflicting needs. The skills a teacher must apply, for example, they must be good at presenting in a face-to-face environment and at the same time good at working in an online environment, which is difficult and stressful. For example, if the instructor is showing attendees how to use a sensor, it excludes online learners from participating. Besides, the teacher assigns a task to do a research (reference) and report on some new device, which is easier to do by those who learn online than those who are face-to-face, who are in classrooms and do not have good Internet or do not bring their electronic laptops with them. This can lead to a decrease in the quality of learning, because the teacher decides to use approaches that are acceptable to both groups, but do not have the same positive effect - for example, to conduct a traditional lecture, which is not good for both groups. Or for the teacher to prioritize the needs of one of the two groups - for example, for online students to be passive listeners and face-to-face students to be more active, or to focus on those students who are online and so that others decide not to come to classes.

The main disadvantage of blended learning is that sometimes the given task may not be completed before the start of the other component. For example, students are tasked to read an article and write a summary on it. Some of the students have prepared diligently, while others have simply forgotten to do so. This puts the teacher in a difficult situation - to spend time on repetition and clarification to stimulate everyone to do the work, or to move on, knowing that some will fall behind. In this case, the bet is on the learners themselves – they must understand and believe in the importance of each of the components of blended learning and be motivated to do it and complete their tasks on time.

It can also be argued that blended learning also requires the teacher to possess two skills as in hybrid. But is it so?

- The teacher must not teach both online and face-to-face at the same time. He can only focus on one thing.
- The sequential approach makes it possible for different faculty to handle the different components – one checks the online assignments and the other conducts face-to-face training.

The benefits of hybrid and blended learning:

If blended learning is done well, it can bring benefits to students that neither hybrid nor blended learning can.

Blended learning makes it possible to select learning approaches and methods based on the specific situation, considering the needs of the learner and the content. The flipped classroom concept - where learners are introduced to the new subject learning through online sources and then coming together to ask questions and discuss is a very good example of blended learning, demonstrating the potential of blended learning to condense the time learners spend together.

Blended learning offers greater opportunities to personalize learning than hybrid learning. For example, during the face-to-face phase, the teacher considering some of the students' interests and needs or their prior knowledge, which leads to the corresponding adaptation of the content and tasks in the online phase.

Despite these advantages of blended learning, we believe that hybrid has its place in future education, hoping that the development of technology can make it more effective - for example, augmented reality can be actively used in hybrid learning.

In the time of the post-pandemic learning period, in which we return to face-to-face learning again, we hope to apply our positive experience of online learning to a sensible choice of learning methods and approach. When there is a need, let's conduct online training as an extension of the present one in order to improve the learning results.

Blended and hybrid learning are two distinct approaches, and their choice has different implications for students and the learning process that takes place.

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1.5. The flipped classroom (Zhelyazka Raykova and Galin Tsokov)

The experience of conducting training online has shown that the implementation of the flipped classroom as an approach has a place in the future training of physicists and engineers.

Thanks to advances in technology and the new appearance of hybrid learner-centred learning environments, the flipped classroom model has attracted the attention of both researchers and parts of the teaching community (Bergmann & Sams, 2013; Chen, Wang, Kinshuk & Chen, 2014; Howitt & Pegram, 2015; Lai & Hwang, 2016). Research shows that this model can be effective and stimulate learners to interact actively and form high cognitive skills (Bergmann & Sams, 2012; Chen & Chen, 2015).

There are two main factors that promote the implementation of a flipped classroom:

- prevalent distribution of online videos, materials and information;
- poor learning outcomes from traditional classrooms.

These two factors influenced teachers Aaron Sams and Jonathan Bergman at Woodland Park High School in Colorado, and they began recording PowerPoint presentations for their students who missed class (Bergmann & Sams, 2013). These presentations are published online and are gaining great popularity. Students start using the online materials/digital lectures to learn and gain knowledge before the face-to-face lectures. In face-to-face meetings, learners spend more time upgrading their knowledge or getting additional clarifications. Sams and Bergman began lecturing with results from using the flipped classroom method, resulting in other educators adopting the model.

What do we mean by the Flipped Classroom model?

In the classic learning model, the teacher is the central figure in classes and the main source of information. He asks questions, also answers questions and organizes the students' activities and feedback accordingly. Such a way of conducting teaching can be didactically successful and meaningful depending on the professionalism of the trainer. In this model (approach) of organizing the learning process, students' participation is related to activities in which they work together or independently on tasks set by the teacher. Discussions are usually controlled by the teacher, who is also the central figure in the class.

According to Honeycutt (2014) "The flipped classroom can be described as a transition from a teacher-focused to a learner-focused learning environment". It can also be defined as a shift from individual to collaborative strategies. Besides, it is possible to flip a class by using individual activities such as quizzes, worksheets, reflective writing prompts, and problem-solving assignments. The key is to complete these activities during class.

In essence, flipping a classroom involves taking energy away from the trainer and redirecting it to the learners, and subsequently using educational tools to improve the learning environment. Educational tools include but are not limited to the use of technology" (Bergmann & Sams, 2012) While videos and other technology tools can be effective in the flipped classroom, they are not required. The flipped classroom shifts the directions of communication to a student-centred constructivist model where deeper topics can be explored, and student participation can be more active and conscious. In this model, the role of modern technologies is key, providing online access to information, recorded lectures, assignments, tests, etc. forms to deliver the learning content to students (Hamdan, 2013).

According to several researchers, this form of organization of training can increase its effectiveness, motivation to learn, as well as promote teamwork. This is because the flipped classroom supports learning in which the teacher presents to the learners before the class (via online texts, video lesson, videos) key points of the learning content. Students are introduced to learning content at home, which allows classroom learning time to be used to actively develop their learning skills through discussion and debate. Particularly important is the constant formative feedback provided during the flipped classroom, which helps educators assess student achievement.

The meaning of the concept of "turning" is redirecting the focus in the learning process to the learner, learner/student.

The most widely used description of a flipped classroom (flipped learning) is a model in which learning activities that normally take place outside the classroom in the form of homework or independent work assignments now take place during class. Activities that traditionally take place during classes are, in this model, carried out before the face-to-face meeting. This means that students pre-complete an assignment that involves watching a video, which can be a recorded lecture, a demonstration, a practical film, etc. After arriving at face-to-face classes, students work on assignments together with their peers and the instructor.

The flipped classroom is based on the constructivist approach where learning is an active, cognitive and social process. Learners can use their previous experience and existing knowledge to build an understanding of the new material. Using this model helps students stay in touch with the teacher for more time, doubling student access to the teacher - once with the videos at home and again in the classroom, increasing the opportunity for personalization and more precise targeting of learning.

Flipping the classroom supports learning in which, the teacher shows learners before the face-to-face class "fundamental concepts, through online texts, video tutorial, videos and activities and ensures that class time will allow learners to actively exercise their cognitive functions" (Findlay-Thompson, Mombourquette, 2014). Particularly important is the constant formative feedback provided during the flipped classroom that helps educators assess student achievement.

Flipped learning "focuses on meeting the student's individual knowledge needs through a clear set of rules, in a way that differs from established methodology. The four pillars of F-L-I-P are: flexible learning environment, learning culture, planned content, and professional trainer" (Hamdan, 2013). There are different models of flipped learning, and according to the learners and their needs, the most suitable one is chosen (see 7 Unique Flipped Classroom Models – Which is Right for You?).

A standard flipped classroom. Students are assigned "homework" - watching video lectures and reading material related to the next day's lesson. During classes, students put into practice what they have learned through traditional classrooms, with educators having the opportunity to give individual attention to each of them.

Discussion Oriented Flipped Classroom. Lecturers recommend watching lecture videos as well as any other videos or texts, YouTube videos and various resources related to the topic. Time is then set aside for discussion and exploration of the topic.

Demonstration Oriented Flipped Classroom. Especially for those subjects that require students to remember and repeat actions accurately - chemistry, physics and mathematics - it is most useful to have a video demonstration available that can be paused, replayed and watched many times. In this model, the instructor uses screen recording software to detail their actions in a way that allows learners to follow their own pace.

A "fake" flipped classroom. This idea is perfect for younger learners for whom real homework isn't quite right yet. Instead, they watch the instructional video in class, allowing them to review the material at their own pace.

Flipped classroom by groups. This model adds a new utility that encourages students to learn from each other. Learning begins the same way with instructional videos and other resources shared before class. The change occurs in the attended lectures, when the task of the day must be completed in a group. This format motivates students to learn from each other and helps them explain their answers and choices.

Virtual Flipped Classroom. For educated adults and in certain courses, the need for face-to-face lectures may disappear completely. Online learning platforms are used. Individual consultation with a trainee is allowed after a pre-arranged meeting.

Role reversal. An instructional video created for the purposes of the flipped classroom does not have to begin and end with the teacher. Students can also use the video to better demonstrate their skills. Assign the students tasks with engaging in various role-plays to demonstrate competence, or ask them to record their own videos.

A modern learning model is the combined strategy of implementing the flipped classroom and online project-based learning (FC-OPBL) in order to improve the quality of teaching and the effectiveness of the learning process. Flipped classroom learning design is used as an organization strategy and OPBL as a learning method (Wen-Ling, Sh., Chun-Yen Tsai, 2017). Thus, online project-based learning (OPBL) is a popular approach that uses technology to increase the effectiveness of the educational process. Databases on the Internet provide students with a rich and varied learning environment outside the classroom, while email, online forums, and cloud platform tools help them communicate and collaborate.

Training using the FC-OPBL flipped classroom approach to facilitating online project-based learning model is organized as follows:

Preliminary organization:

1. Creating micro video lessons - we shoot a video explaining new learning content.

The teacher can add explanations in written or audio version. Free educational resources from the Internet such as Cannes Academy, Ucha se, e-textbooks are used. The video created by the teacher is made available for online access to students on platforms such as YouTube, TeacherTube, Screencast.com, Google Drive).

Variety: an online micro-lesson of 10-15 minutes explains new learning content.

1. Group organization of training
2. Differentiation of teaching, through TEAMS

Distinguishing instructions when structuring teams. Depending on the project, formation of homogeneous or heterogeneous teams. Teamwork and collaboration are possible in virtual space. Collaboration, but also individual instruction in online and offline learning (Google Classroom makes this possible).

The **technology of conducting lessons on the model of the Flipped Classroom** / Flipped Learning can be traced through the dynamics of the activities of the teacher and the student.

Instructor's Activities:

- In a classroom session, the instructor gives instructions and guidelines related to the studied topic. He sets assignments for the students from the textbook that they must work on.
- Instructor indicates a link for meetings, or his e-mail address, through which they can communicate with the students until the next class he attends. He must be ready to answer questions posed by them.
- Instructor checks the online solutions of the assigned learning tasks, which are placed in the cloud.
- The next present lesson is conducted according to the set goal. If practical skills are to be formed in a laboratory, students are pre-acquainted with the equipment, the tasks to be performed and the theoretical foundations. This saves a lot of time spent in the laboratories and provides an opportunity to spend more time on the task itself. If the classes are not practically oriented, the teacher should prepare scenarios for an upcoming discussion, or discuss a case study or problems related to the studied topic. He/she must be willing

to apply interactive methods to give access to every student to participate in discussions and to set formative assessment. Tracking progress and evaluating student's activity is very important to be able to regulate the quality of the learning process in this model.

- During face-to-face meetings, lecturers are more like advisors or mentors who support group activities.

Student Activities:

- In the present lesson, he/she must understand the task set for independent work and in what form the results are expected. Asks clarifying questions and makes comments.
- Plans working hours and performs assigned tasks by reading literature, watching video materials in the context of assigned tasks.
- Actively uses the Internet. Ask questions to the teacher online if necessary.
- Completes assigned tasks by preparing presentations, solving tasks, preparing frameworks of protocols for laboratory classes, etc.
- At the subsequent attendance lesson, he/she presents the implementation of the independent work, participates in discussions, performs a practical exercise by collecting experimental data and processing them.

Example of flipped classroom physics lesson scenarios: Idea for the example, a similar model is described in the guide "Flipped Classroom Method Study Guide in Adult Education" (2015)

An **example** is linked with the proposal is related to the study of a section of physics, according to the teacher's program. A textbook is chosen that the teacher traditionally works on. For example, that of Giancoli D., Physics (https://www.docdroid.net/ OFMOth4/giancoli-physics-principles-7th-ed-pdf#page=7). It is good to have ready-made online learning resources for the textbook, as with the given example it is "Mastering Physics" - https://mlm.pearson.com/ northamerica/ masteringphysics/. Of course, together with the textbook, students can be offered video recordings of the lectures of the teacher himself, or video recordings of practical exercises that will be performed.

Some **imperfections** of the Flipped Classroom model:

- The justified burden falls on the independent work of the students, and in case they do not have the skills for this, it leads to difficulties.
- Sometimes it is possible to overload the students.
- Provided that they are not well prepared, the risk of failed classes in the present phase is high. It is also possible that some students do not actively participate in the classes they attend. Some of the students may take the passive side in the learning process and expect instructions.
- The teacher is required to spend time preparing learning resources for students' independent work and to revise the curriculum in a new way.
- Difficulties also appear in the evaluation of the results of the academic work.
- The teacher may find it difficult to produce quality video materials and therefore needs help from specialists, which is a kind of difficulty

Many of these challenges can be overcome if the instructor is well prepared and motivated to work in this way.

Advantages:

- By video recording his lecture, the teacher can emphasize important critical ideas that will be discussed in the present phase. It can also manage the pace of learning the individual topics of the curriculum.
- The recorded lectures can be watched repeatedly by the students, they can scroll them, take breaks, use the Google translator or its information search capabilities.
- Attended classes no longer have the character of lectures, but of workshops/ seminars in which learners can ask questions related to the topic, work in groups and carry out practical exercises.
- The flipped classroom changes the role of trainers, who give up their leading position in favour of active and collaborative work during the learning process.
- The flipped classroom model makes the students' responsibilities bigger and gives them the opportunity to experiment more. To date, the flipped classroom has been used primarily in higher education.

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CHAPTER 2

CLOUD TECHNOLOGIES IN EDUCATION IN PANDEMIC AND POST-PANDEMIC TIME

2.1. Cloud technologies in education (Stefan Stoyanov)

Although gaining popularity before the COVID-19 pandemic, cloud technologies have become indispensable during the lockdown, especially in education. These technologies are one of the sought after and actively developing areas of the modern IT world. The use of cloud technologies in education has opened great opportunities for all kinds of educational institutions, both for teachers and learners. Their use in education in 2021 reached an economic effect of 25 billion dollars (Riddle, 2022)

So what does this mean for the current and future development of education? What are the main advantages of cloud technologies in education?

Let's look at some of the **benefits**:

- ***Improved administration in educational institutions***. Cloud technologies provide easy collaboration between different administrative units and save money and time in the process of solving problems. Through them, the service is provided quickly and immediately, in different parts of the day and from different places.
- ***Improved teaching process***. Using cloud technologies, educators have greater opportunities to activate student learning by reaching a wider audience of students and managing their learning. They also make it easier for educators to prepare interactive learning content, prepare online tests, and facilitate

communication with students. Grading tests, project results, student assignments and giving feedback has never been easier.

The long-term vision is to shift current teaching practices to project-based learning and create opportunities for more interactivity, stimulating students to conduct their own research, analyze data, and come to important conclusions independently. For the implementation of this model, the role of cloud technologies is leading.

Plovdiv city (Bulgaria) has been recognized as a role model for its efforts to fully digitize the educational process by multiple organizations, including Google and the Innovation in Politics Institute, and is the winner of the Smart 50 Award 2021.

Since 2018, several Plovdiv schools apply the **"1:1" model** in their education. This is a model of organization of the learning process, where each student and teacher have their own electronic device and a personal profile connected to it. The model considers the use of digital technologies as a resource and a platform, not as an end in itself. The "1:1" model assumes that teachers and students have access to all the content that the Internet offers (or any other set of content) both in the classroom and anywhere. In this model, students do not use notebooks or other paper information carriers.

Some of the features of this model that apply to students and teachers are as follows:

- have a personal portable computer and permanent access to the Internet;
- study, work and communicate in groups, both inside and outside the classroom;
- create products that use their knowledge and skills from different subjects;
- spend their time in front of the screen in a meaningful way and master the latest digital tools;
- are in a secure environment, physically and online;
- plan lessons together.

The "1:1" model has been proven to significantly increase students' motivation to learn and active participation in lessons, which in turn has a positive impact on their grades and overall performance. It allows for a better emphasis on competency-based education, where students are expected to become designers of learning resources and create new content themselves. Currently (academic year 2022-23) there are over 100 classes in the city where students work only with personal laptops and the entire learning process is digitized. As of October 2022, there are over 40,500 active accounts in the municipal education system, with nearly 14,000 virtual classrooms. The conducted research on the quality of this model showed that most of the teachers (80 %) believe that this model is successful and should continue to be implemented in Bulgarian schools. The experience of the municipal schools in the Municipality of Plovdiv shows that the introduction of cloud platforms has become the basis for both the creation of new and the development of already existing innovative practices in school management, educational activities and the educational environment in general. Cloud technologies also create better conditions for teamwork between educators and students and school management. They are realized thanks to the following capabilities of cloud technologies:

- ***Quick and easy access to information***. By using cloud technologies in the classroom or in the self-training of students, the Internet is available 99.9 % of the time, which is very convenient for all participants in the educational process.

  This leads to the following *consequences*:

  - Both students and educators can implement learning opportunities virtually at any time, resulting is huge time saving. Permanent access to course materials removes barriers to accessing information for students who are physically unable to attend classes in person.
  - Sharing notes has never been easier than with the use of cloud technologies - the user can share or receive notes from any area covered by an Internet connection and at any time.
  - Data safety is no longer a problem as it is all collected and stored in the cloud and there is no need to worry about it being kept on the computer or carried around on a flash drive that can be forgotten or lost.
- ***Online education courses***. The rapid development of online educational courses in recent years is a consequence of the introduction of cloud technologies in education.

With cloud technology, every student has access to online educational courses offered on *Coursera* or those that are associated with some educational institution - school, college or university. When we talk about **Coursera**, we mean that it is the largest project in the field of online education, developed in 2012. By 2017, the service was used by more than 24 million users. The project includes courses in physics, engineering disciplines, humanities and arts, medicine, biology, mathematics, computer science, economics and business. **Coursera** runs on *the Nginx web server on Linux machines leased from Amazon Web Services*. The data is stored in Amazon S3 and the site is searched using Amazon CloudSearch.

A similar platform that offers online courses for teachers to the European Commission is the **European Schoolnet Academy** (European Schoolnet Academy, 2022).

- ***Competitiveness.*** Nowadays, learning using cloud technologies can compete with the traditional educational process. It should not be forgotten that cloud technologies make high-quality self-learning possible. Increasingly, employers are accepting potential employees who prefer e-learning to face-to-face.
- ***No need for expensive hardware and expensive software***. Since the core concept of cloud technology means connecting to cloud-based applications, neither students nor educators need specific devices to access course resources. Cloud programs are perfectly compatible with any device. Even a cheap smartphone allows you to connect with related academic applications.

The **SaaS model** is considered one of the biggest advantages of cloud-based computing. The acronym SaaS (software as a service) stands for software as a service and is defined as a method of licensing and delivering software where the software is available online rather than installed on a device. It is common for these software applications to be available to students for free or at a very low cost, making learning accessible to most students.

- ***Saving money on expensive textbooks***. College level textbooks are known to be an expensive indulgence, so more students are refraining from buying them. Cloud textbooks are the only solution to this problem. Digital books are generally less expensive and allow lower-income students to also be able to access high-quality learning. The implementation of cloud technology eliminates financial inequality, placing students of all statuses in the same educational environment.

2.2. Advantages and disadvantages in using Moodle as learning management system in teaching activities (Ion Buligiu, Cristian Marius Etegan)

During pandemic, the teaching activity had to focus on methods and tools of distance work, online and offline, so that faculty could provide students with study materials and the process of teaching through online video communication sessions. We will emphasize both the advantages and disadvantages of using online learning technologies and tools, both from the perspective of instructors and students, to highlight the positive aspects and delimit the negative ones, to identify the elements that can be used successfully in the post-pandemic period. The experience gained in the use of these technologies helps us to adopt more efficient teaching methods in the future, by combining classical and digital learning mechanisms, creating useful content for students, in a format that is as attractive and easy to understand, and can be accessed from anywhere and anytime.

Current education is tending to make more and more use of the tools, resources and services offered by the various online platforms that allow online content to be published and easily accessed, systematizing learning content into an attractive form for the student, provides fast and automatic evaluation mechanisms, as well as a wide variety of modules for video conferencing.

An example of the use of such a platform is given by the Moodle learning management system, on which we will conduct a study to highlight the advantages and disadvantages of the pandemic period, considering the experience of working with it over a period more than two years. The use of such a platform has resulted from the need to identify an effective solution in the organization of the teaching process and to provide the best possible interaction between students and instructors, to achieve a performance in transmitting to students the notions needed to be assimilated, structuring them in an accessible and easy-to-follow form, but also carrying out an evaluation of the learning outcomes.

Moodle offers a multitude of modules and tools for online learning management, so it can be considered an advantage from this point of view, but there are problems related to its complexity, faculty facing a real challenge in choosing the right tools for teaching activities, students may face problems related to the standardization of content for different disciplines (each teacher will choose their own tools for structuring the subject they will teach).

The working interface for a student is becoming more and more complex, as the resources offered are very varied (files of different types, media feeds, links, slide-show presentations, automatic assessment modules, poll tools etc.), thus creating problems in ease of use. In addition to this learning platform, faculty and students interact through online video meetings, email, instant or phone messages, using a variety of applications (Zoom, Google Meet, Microsoft Teams, Webex, Skype are just a few of them), which leads to a decrease in the student's ability to choose the appropriate format for communication, as well as the difficulty of selecting the most appropriate solution to share or transmit the results of his study.

It is thus noted that it is necessary for educators and students to have additional skills in the use of so many communication tools, to achieve an effective educational process, while the fact that educational institutions must have hardware equipment (network infrastructure, routers, switches, servers, computers).

The pandemic period caused the education system to adapt to restrictive conditions, but these measures created opportunities that favoured the emergence of new innovative teaching and learning methods based on new technologies, one of which was e-learning platforms, and the study our focus will be on the capabilities of the Moodle platform.

Following the experience gained during the pandemic, it was easy to see that the involvement of students in the education process was greatly diminished during the online teaching sessions by the numerous situations in which they closed their video camera or invoked technical reasons, the teacher no longer having visual feedback on the audience and last but not least the creation of an uncertainty that the student is attentive to what is being taught and does not deal with anything else. It is very important that the student-teacher visual connection is well established because it allows the teacher to assess students' understanding of the concepts taught, regardless of whether the teaching is done online or in class.

The Moodle online platform also has automatic mechanisms for students to attend classes, which can be set to record student participation in class throughout the activities, by validating the actions of response to quick quiz or poll tests, as long as they have gone through the tutorials provided and if they have listened to them in full, access to the next module may be restricted if the student has not fully completed the current stage.

A partial solution to these drawbacks would be to evaluate quickly by asking short poll questions to students at certain intervals, using online platforms, which will lead students to be careful to answer the teacher's unexpected questions correctly, and the teacher can assess how many students were attentive and understood the notions taught and possibly corrections can be applied to the educational process, by clarifying the unclear elements and discussing what was not understood by students who did not answer the poll questions correctly.

Students' active participation in classroom activities can be monitored by handshake systems to ask for clarification or to answer the teacher's questions, assimilated by choosing the correct answer from several options.

Creating groups at the platform level is also very useful because they develop teamwork skills, the teacher can interact more easily with groups of students and can more easily adapt teaching materials to the skills of students in the group.

In the post-pandemic period, taking into account these experiences, it is possible to use hybrid teaching solutions, in which, at the same time as teaching in the classroom, to use the resources offered by online learning platforms, through which the course content to be structured in modules, which are divided according to the schedule of teaching activities, in which students can access useful components such as video sequences to explain the different notions, Wiki sections whose content can be completed by students, regular assessment through quiz sessions, online questionnaires that reflect student satisfaction and more.

We will see what are the teaching methods and techniques that can be adopted in the post-pandemic period, based on the experience gained in the pandemic period, by highlighting the most appropriate components that have proven to be effective in the teaching and learning process and their insertion in the current educational process, which will certainly be a hybrid one, by combining the classical teaching methods with those that use the new technologies and their application also at the level of the learning activities carried out by the students.

Our study will be based on the SAMR (Substitution, Augmentation, Modification, Redefinition) model, which will highlight the microlearning method, which is based on learning in small segments, easy to assimilate, with a rich content of visual components and which summarizes the important elements of the main course.

To better explain these teaching methods, we will first explain the SAMR model, which applies strategies for implementing new educational technologies structured on four levels (Fig. 2.1.)

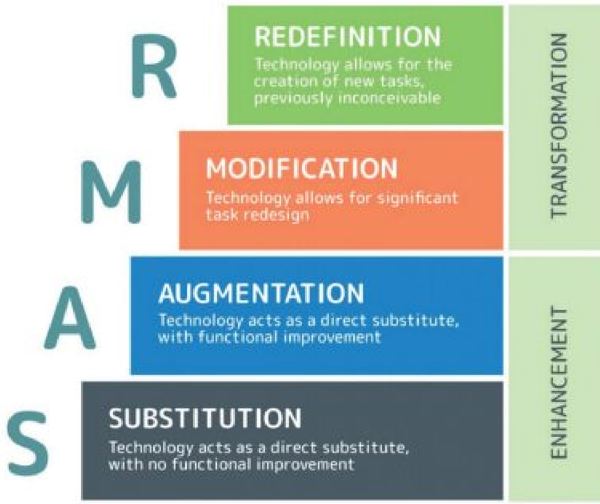


Figure 2.1. Implementation levels of the SAMR model

The first two levels, *substitution* and *augmentation* will be based on activities through which technology is used as a direct substitute in teaching methods, to achieve an *improvement* in the educational process, and the level of *modification* will allow a redesign of tasks, assigned to students to achieve better results and then by *redefining* new tasks will be created, which improve the previous components through a process of *transformation*.

We will further explain the implementation mechanism of each level within the SAMR model, to highlight the opportunities created in the teaching and learning process.

The *substitution level* contains the first phase in which technology is used as a substitute for traditional handwriting teaching methods, with electronic documents appearing instead that can be easily written, modified and distributed online. During this phase, both students and educators will become familiar with new writing technologies by using word processors, creating PowerPoint presentations, using spreadsheets to make calculations very easy, converting documents to portable PDF format, creating and completing online questionnaires to feed and evaluate feedback and finnaly upload these resources to online learning platforms such as Moodle.

The *level of augmentation* means that technology allows students to understand more complex course content using of additional media elements in the course such as video tutorials that explain current notions or links to documentation resources related to the content explained, PowerPoint presentations that summarize the essentials of the course and contain suggestive diagrams or even short explanatory videos. Basically, the teaching activity is complemented by media elements of this type that segment the complex content into smaller components that contain explanations, thus transforming the course into an accessible and easy to assimilate content.

The *modification level* brings in the teaching process interactive tasks for students, which involve the creation of documents shared by several participants, allowing the development of teamwork skills in a collaborative environment such as Moodle. Video chat rooms can be set up for brainstorming sessions where students can discuss common topics of discussion or a specific topic or to jointly solve tasks. Another interesting form of knowledge presentation is the production of video podcasts in which students can present a specific topic and which can then be accessed by other students and instructors for interesting and constructive discussions.

Redefining is the most complex stage of the SAMR model, through which completely new opportunities in learning activity will be created. It will create the opportunity for the student to maximize their potential by creating authentic research content and developing skills to adapt to new developments in the field. This can be done by connecting students with academic and research backgrounds from other universities both in the country and around the world, encouraging students to publish their research in online journals, and attending conferences. Moodle also offers multiple possibilities to insert in the course section of the materials developed by students and their discussion, the use of forums containing discussion topics with question-and-answer sessions, e-voting systems, podcasts, pages Wiki, workshops sessions and so on.

In the literature (Hug T., 2005), *microlearning* as a teaching method is characterized by the following elements: segmentation of learning time into shorter periods, which does not require the student to a prolonged assimilation effort; dividing the complex course content into smaller and easier-to-understand components; synthesizing important notions from the course; encouraging an atomic structure of the course; creating coherent and autonomous content; the use of media elements and interactive components in the structure of the taught material; providing support for different ways of learning.

The emergence of microlearning as a teaching method is based on the principle that students are subject to very high cognitive demands when they have to assimilate a complex and large course content. This overload leads to a reduction in the student's learning performance, the risk of the student becoming tired and not fulfilling all the tasks imposed by the teacher, thus leading to gaps in the education process. If the total learning effort is divided into smaller segments, by atomizing the course into simpler and smaller components, with a very clear structure and easy to assimilate, then we will get a better performance from the student in the learning process.

Specifically, the solution can be easily implemented on the Moodle platform by structuring a very complex course in the form of micro-content media components, such as inserting PowerPoint presentations or Prezi explaining the course segments into subchapters or placing YouTube video content that to explain a specific topic, giving the student the opportunity to access them directly from the platform and to assimilate them at their own pace.

Certainly, better results will be obtained from students in their learning process, along with an increase in their efficiency and performance if the large course content is divided and has a long presentation time into well-organized subcomponents, on smaller segments, rich in visual content and much easier for students to assimilate. This will make the transition from a classic, formal course content to a modular structure that can sometimes have an informal, pleasant way of presenting, which will attract students in discussions with the teacher or between them, combining the advantages offered by the online platform.

On the *Moodle* online platform, you can use quick assessment components in the form of quizzes, or the completion of short online survey questionnaires, so that the teacher can get quick feedback on how students assimilate knowledge and can proceed to provide additional explanations or discuss unclear notions to students. At the same time, this system offers the teacher the opportunity to interact better with students, including the placement of homework associated with each course segment, as a challenge for students, as they can upload the solved topics in the Moodle module. These can be easily evaluated and rewarded by the teacher.

Microlearning method can achieve several positive results among students, such as: a better assimilation of the concepts presented in the course, a greater interactivity with students in the teaching activities, students will have an increased motivation to learning, develops the ability to learn and collaborative research, increase student performance and learning ability.

It must be said that there are opinions (Jomah O. et al, 2016) that microlearning method would not be suitable for the acquisition of complex skills or in the case of intensive teaching courses, where the student must perform complex tasks and assimilate notions with a high degree of difficulty at a relatively short time. As a result, further research is certainly needed in the absence of sound empirical information, along with the presence of impact assessments on the application of these methods.

2.3. Using Google Classroom platform in teaching activities during the pandemic time (Silviu Constantin Sararu)

At UCv the COVID-19 pandemic "began" on March 12, 2020, when the Administrative Council of UCv decided to suspend direct teaching activities ("face to face"), as well as all related activities (scientific conferences, student/school competitions, cultural, artistic and sports events, debates, other meetings or public events etc.) until March 31, 2020. According to the same document, during the period 13-31.03.2020, teaching activities will be carried out online using the EvStud platform or e-learning platforms (Moodle, **Google Classroom**), faculty and students benefiting from the necessary support in the field. At that time, e-learning platforms (but not Google Classroom) were used in the UCv for reduced frequency and distance study programs, according to the legislation in force. UCv students could use a web module of the EvStud platform which at that time offered the possibility of accessing different information (grades, curricula, thesis/dissertation, etc.). Faculty also used this platform. For students, access to this platform is achieved through PIN and a password. At the time of the suspension of teaching activities, students did not have an e-mail address for the *ucv.ro* domain (the UCv domain). Teaching staff had the possibility of using an e-mail address for the *ucv.ro* domain, but the majority did not use such an e-mail address.

In the days immediately following the suspension of direct teaching activities, the IT and Communications Service of UCv generated email addresses for the *ucv.ro* domain for academic staff and all students (*name.firstname.cod@student.ucv.ro* and respectively *firstname.name@edu.ucv.ro*), the EvStud platform has been modified to allow the transmission of course and seminar notes and support materials for laboratory activities to students. Through these e-mail addresses, students and faculty could also access the *Google Workspace for Education* e-learning platform, which allowed the use of **Google Classroom**.

Google Classroom allows an approach to education that combines the possibility of posting materials online by faculty and students with the opportunity of online interaction between faculty and students with traditional teaching methods. This is possible since Google Classroom integrates various applications developed by Google (Google Drive, Google Meet, Gmail, Google Docs, Google Sheets, Google Slides, Google Forms, Google Calendar).

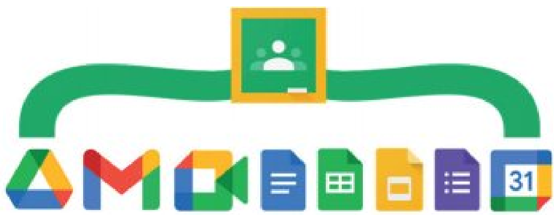


Figure 2.2. Google Suite Application

Starting with the year 2020, Google Classroom was integrated with Google Meet to cover the needs of conducting online video direct teaching activities.

How to use Google Classroom - brief presentation

A first step for using Google Classroom is to log in to the www.classroom.google.com web page. At the first login, the "*teacher*" or "*student*" status is selected. This is a very important step, because if you select "*student*" you are not allowed to create a class.

Once you have logged in and identified as a teacher, the next step is to create a class. For this, press the button with the "+" symbol.

Figure 2.3. Creating (or joining) a class options

and two options "Join class" and "Create class" appear. Select the desired option. If the second option is selected (to create a class), a menu opens in which different information about the class is requested. The only mandatory information to enter is "Class name", the others being optional.

Figure 2.4. Completing class details

At the beginning, the class will look like in figure 2.5 and can be customized by pressing the "Customize" button.

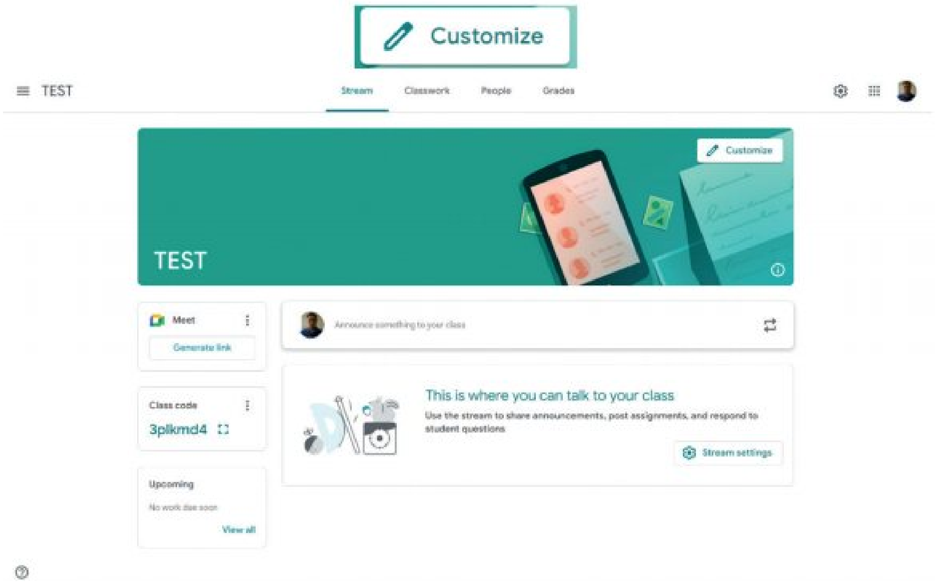
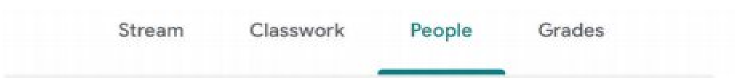


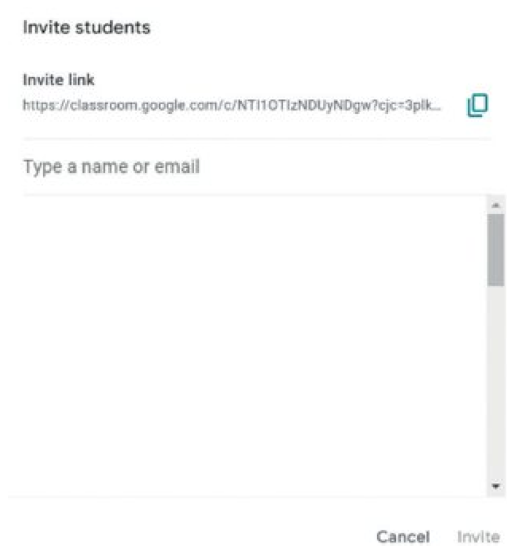
Figure 2.5. Customize a class

"Class code" (in our case this is *3plkmd4*, it differs from one class to another and can be reset) displayed on the left side represents the alphanumeric code of the class. There are several possibilities to invite students to join the class. One of them is the transmission of the class code to the students (for example via email) and the students enter the class code when they press the button "Join". If you have a list of email addresses of the students you want to invite to the class, proceed as follows. At the top of the screen is a menu that contains the following buttons "Stream", "Classroom", "People" and "Grades".



Press "People", in the new tab that opens press the button to add students.

and in the open menu



fill in the email addresses of the students and press "Invite" from the bottom of the menu. Students will receive an email with the invitation to join the class. To invite other instructor to the class, proceed in a similar way with the observation that the "Invite teachers" button will be pressed

Pressing the "Stream" button opens a page where all the information about the activities in the class appears, announcements can be sent and comments can be written by the other members of the class (including students).

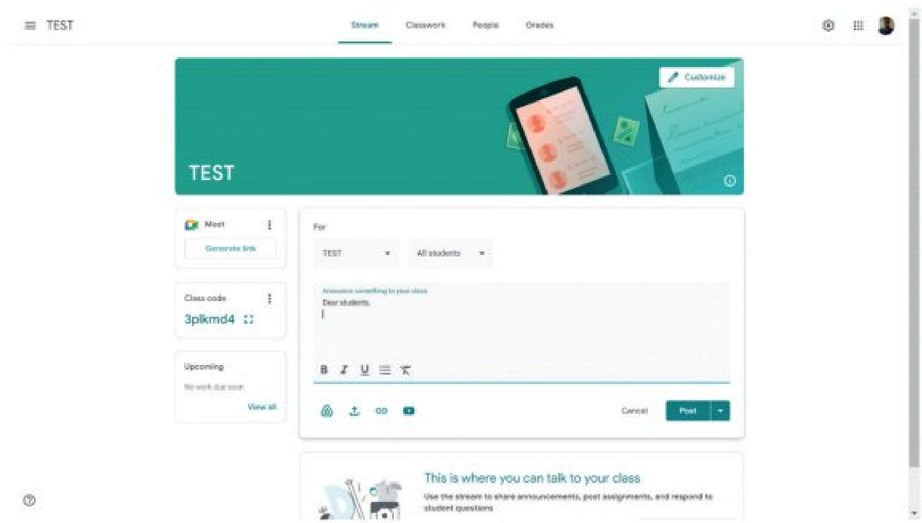
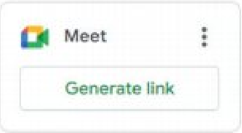


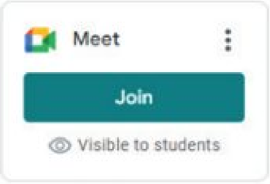
Figure 2.6. Class stream customization

The announcement may contain only text or may constitute other materials (files, links, etc.). Materials are uploaded from the computer of the person making the announcement or from Google Drive, which is integrated with Google Classroom. Google Classroom is also integrated with the YouTube platform (youtube.com). This allows video files posted on youtube.com to be added to the ad.

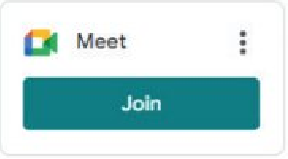
For the live online video activities with the students in the class, the application Google Meet is used. As I mentioned before, Google Classroom is integrated with Google Meet. To use Google Meet application initially, a link must be generated by pressing the "Generate link" button in the "Stream" tab



which will allow students to participate in live online video activities by pressing the "Join" button on the "Stream" tab



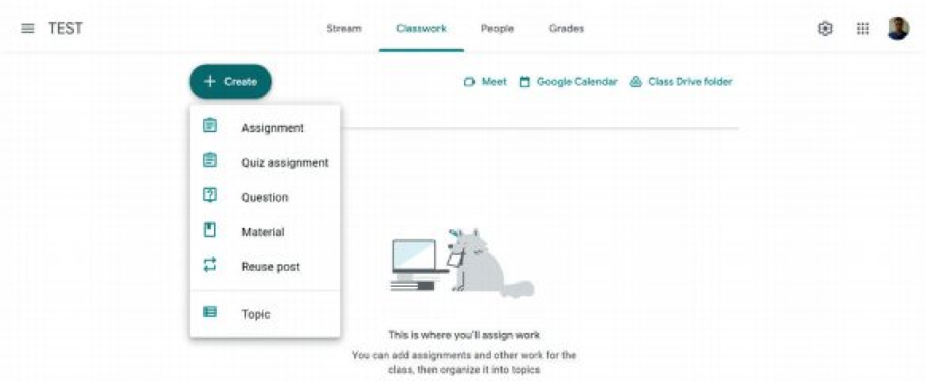
Teacher view



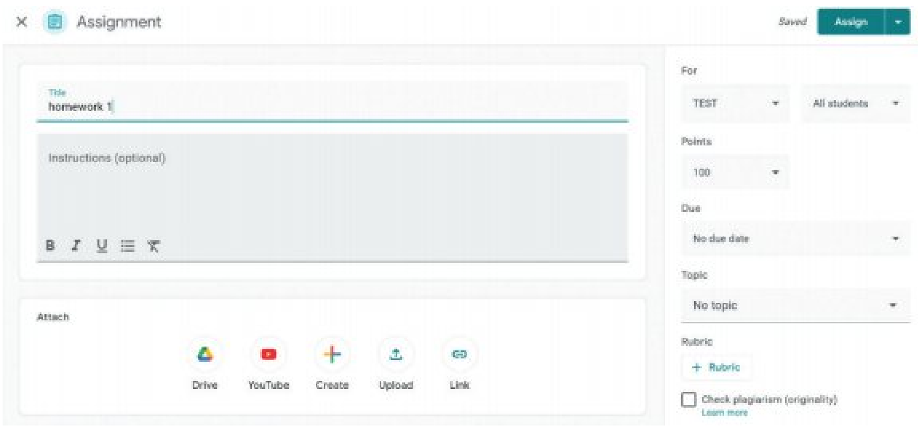
Student view

The live online video activity is initiated by the teacher and the students join as participants.

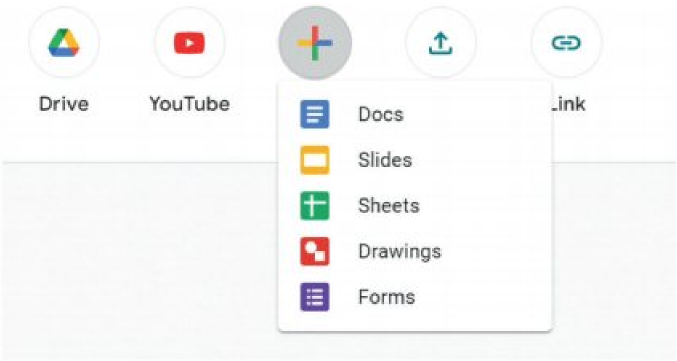
Pressing the "Classwork" button opens a tab that allows the assignment of different tasks (assignment, quiz assignment, question) to students or the transmission of materials (video files, books, course and seminar notes or support materials for laboratory activities).



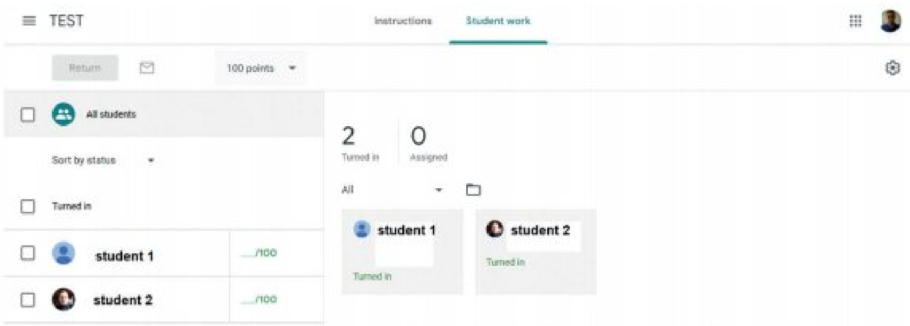
To assign a task/homework, press "Assignment" and a new tab will open



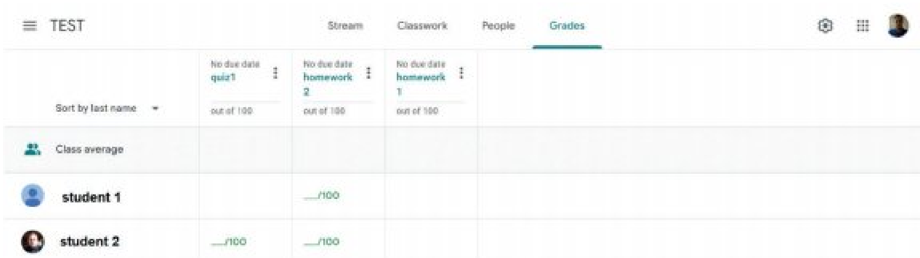
Fill in the fields (the "Title" field is mandatory) with the necessary information. Attach related materials if they have already been created or create them by pressing the "Create" button. After pressing the "Create" button, a menu opens.



This menu allows the creation of materials using Google Docs, Google Sheets, Google Slides, Google Forms, the files being automatically saved in Google Drive. To check an assignment, click on it, in the open menu select "Turned in" and open a tab from which "Student work" is selected.



By pressing the "Grades" button, the Teacher has access to the situation regarding the performance of tasks by the student, scores obtained for homework etc.



Before March 2020, e-learning platforms were characteristic of reduced frequency and/or distance learning study programs. After the students returned to the classrooms and laboratories, some faculty continued to use different modules of the Google Classroom platform. The distribution to students of course and seminar notes and supporting materials for laboratory activities is one such example that does not involve financial resources for the multiplication of these materials. The use of the infrastructure acquired during the pandemic for video recording of courses and distribution to students (and possibly other teaching staff) contributes to improving student preparation and course content, considering that students can provide feedback through the platform. Before the pandemic, solving course and lab activities assignments it was done on paper. The management and organization of the assignments by faculty requires an important time resource. Using the Google Classroom platform, students can send the materials directly to the professor, and he no longer wastes time organizing the documents, this being done automatically by the platform. Thus, the use of Google Classroom allows a better organization of teaching activities, saves time and material resources and offers the possibility of quick feedback from students.

2.4. Zoom – video conferencing platform – another tool in education during the pandemic crisis (Iulian Petrisor, Mihaela Tinca Udristioiu)

Why Zoom? Along with other platforms such as *Google Meet*, *Teams* or *Webex*, the *Zoom* platform was a solution for education, in a crisis such as the Covid-19 pandemic. Among the advantages of *Zoom* compared to other platforms is that it can be installed and used very easily, it connects people from anywhere, it is interactive and allows the viewing of files by meeting participants. For that is why we used *Zoom* at the very beginning to organize conferences from European projects that could not be suspended. Starting with April 2020 and until March 2022, the *Zoom* application was used in carrying out online activities at the UCv (Romania). At beginning, *Zoom* was used for Faculty meetings and, very quickly, it was easily implemented to communicate with students and then carrying out teaching activities for students.

It is imperative to state that the only training offered by the UCv it consisted in a few files made by the faculty on how to use these platforms, and the Department for Teaching Staff Training (within the University of Craiova) was not prepared to contribute to the faculty's training (in order to obtain digital skills specific to online teaching activities). The UCv management did not pay subscriptions for *Zoom*, its recommendation was to use *Google Meet* and *Google Classroom* which were free for education. During pandemic, most of the UCv Faculty's members used the free version, which is a simplified version with limited usage time (40 minutes).

Even if the COVID-19 restrictions were lifted from March 2022, there were hybrid activities that required the continued use of the *Zoom* application. Certainly, the education will never be like it was before the Covid-19 pandemic and it should identify and embrace the advantages of online education. It is currently running a form of transition, of hybrid education, and we must prepare to optimize and improve it.

Why *Zoom*? At the beginning of the pandemic, Faculty had online discussions with students. After this step, it was decided to use the *Zoom* application together with other applications. Certainly, it was impressive how quickly the idea was accepted and embraced by the students, which shows that this generation is ready for digitalization. The main reason for which was preferred Zoom was that some of the students did not have enough technical means to support large data transmissions (video), or the Internet connection was not sufficient to use video transmissions. Also, UCv has students who live in isolated localities/villages (our students being mainly from Oltenia region, Romania). It was obvious that they need a bit of help to participate in the didactic and extra-didactic activities, both from the undergraduate study programs and master's degree. Surprisingly, the participation in teaching activities increased suddenly, the number of students who were "present" online was much higher than before pandemic (when all activities were only face to face), a fact that can be explained by the impossibility of leaving the home only in exceptional cases (due to restrictions) and implicitly the need to use the apparent, additional time (unprecedented situation until then).

Short description of the application. Therefore, from the need to be able to communicate effectively and come to the support of students, we started using the *Zoom* application compatible with *Windows*, *Linux*, *iOS* and/or Android, thus, anyone could connect to (*Zoom* meetings) with any device: phone, tablet, laptop or PC, with any operating system. The advantage was that it allowed even students from disadvantaged areas to connect from their phone or computer. The University offered computers, tablets, phones, internet cards to the students from disadvantaged areas. Even before the pandemic at the UCv there were video cameras that allowed quality recordings. All these things helped students from disadvantaged areas, with the possibility to connect. It also allowed students who live in other localities or who worked at that moment, to connect.

We appreciate that *Zoom's* appeal lies in its simplicity. It has a very simple interface and is super intuitive, especially for someone who has used *Google Meet* or *Skype* in the past. Skype did not allow "share", but several people can connect, documents can be sent, it has chat.

A great advantage of the *Zoom* application is the fact that it can be used with minimal installation on the device (phone or laptop), without an actual account. To use different functions, the application must be installed under the appropriate operating system together with the use of an account clearly associated with a functional email. Activating the application requires association with an email account, any active email. With the help of the account, the facilities offered increased significantly. From the moment of the existence of an account, one could use one of the following existing subscriptions (plans/modes of use), made available by *Zoom*, as follows:

- Zoom Basic – a practically free "subscription", in which one-to-one video conferences can be held for an unlimited time, and limited to 40 minutes, if the number of participants is greater than 3, the session expires and must be restarted;
- Zoom Pro – a paid subscription, $14.00/month or $140.00/year. This very affordable subscription allows 100 simultaneous users, 24 hours of continuous meeting and 1 GB cloud recording (per license). It offers the possibility of Breakrooms that make the application more interactive, the participants being able to be divided into smaller groups, working in teams, on different projects/themes. It also contains Pool, a tool that allows questions to be launched in real time, with immediate feedback;
- Zoom Business – adapted to medium-sized companies that involve the use of up to 10 hosts. It includes a dedicated user interface and other features such as auto-generated transcription;
- Zoom Enterprise – adapted to large companies that involve the use of up to 100 hosts, as well as many other benefits, such as the possibility of translating in real time;
- Zoom Rooms: $49.00/month/room;
- Room Connector: $49.00/month/port
- Video Webinar: $40.00/month/host (attendees 100 people).

How we used Zoom... Both, faculty and students, used the *Zoom Basic* version at the beginning. It is looking very intuitive, like in the next images. First step is to connect to Zoom and then to choose what you want to do.

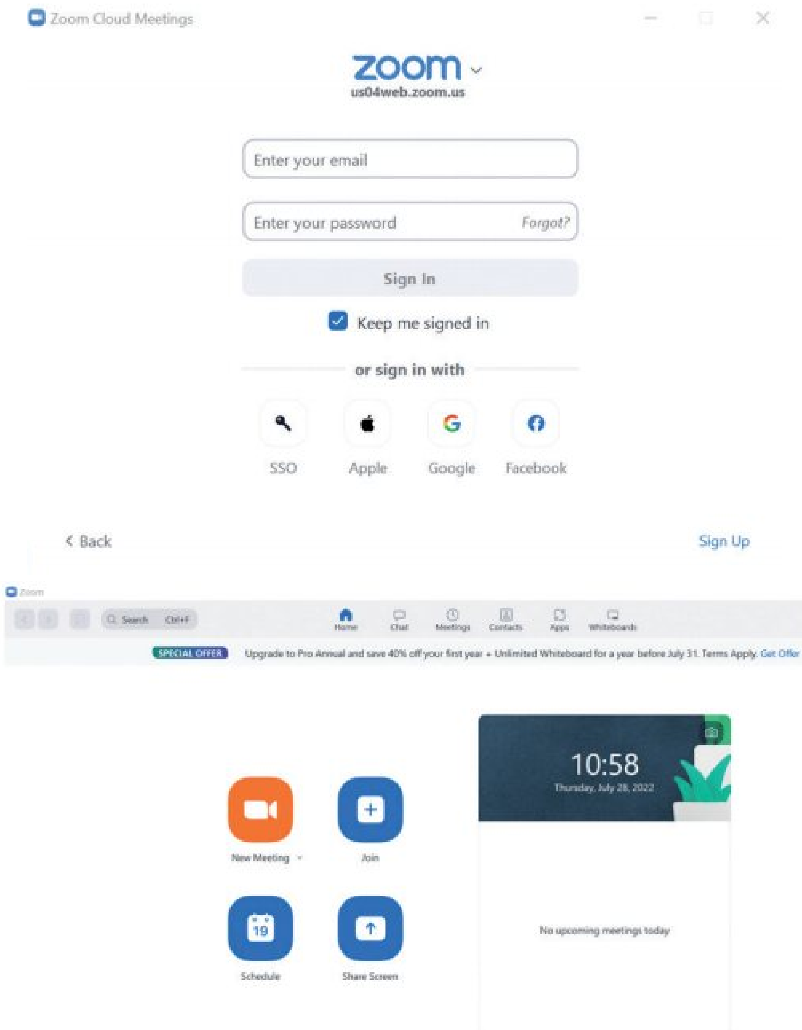


Figure 2.7. Print screens related to connection to Zoom

If it is pushed the button "Schedule", it will be scheduled a meeting with a duration of maximum 40 minutes, in Zoom Basic and unlimited in Zoom Pro. It is possible to establish a recurring meeting, especially when you do not want to change the link for a whole semester or a whole academic year. After it is scheduled a meeting, there are information about the identification of each meeting and will be send to the participants. At scheduled time, the initiator of that meeting will push button Start.

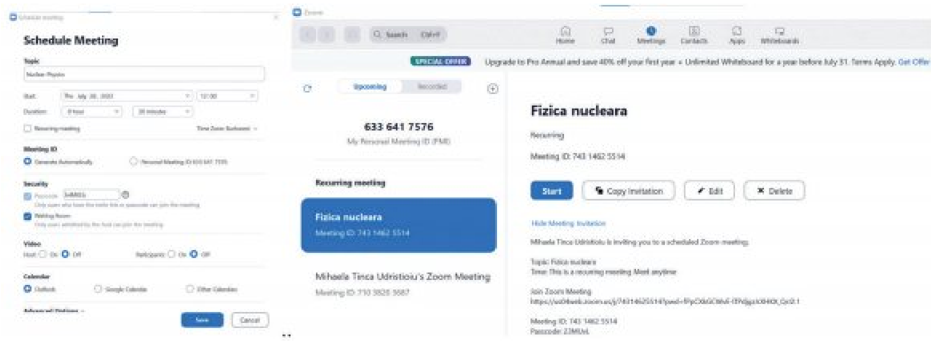


Figure 2.8. Print screens related to the schedule meeting and starts it

At beginning of the academic year 2020-2021, several *Zoom Pro* accounts/ subscriptions were purchased by each department or faculty of the University of Craiova. 100 simultaneous participants were enough to carry out online activities with students from small branches of each Faculty, with one year or study program each. Zoom was very effective to carry out online teaching activities using *Zoom*.

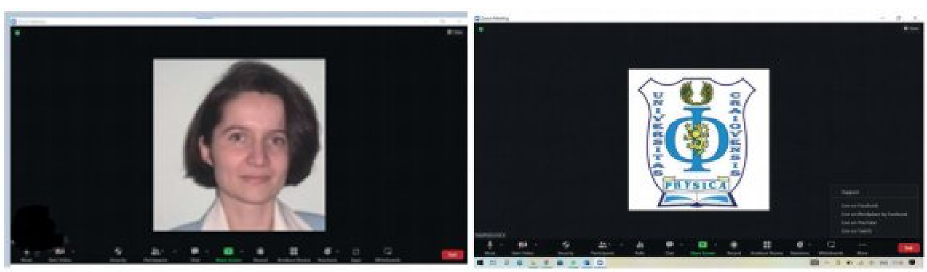


Figure 2.9. Differences between how is looking the screen in Basic (1) and Pro Zoom (2)

Also, the seminar classes were relatively easy to do with the graphic tablets acquired by the teaching staff from own resources. The *Zoom* whiteboard was not very easy to use, especially when formulas and equations had to be written or drawings made. If the whiteboard is combined with a graphics tablet things are improved significantly.

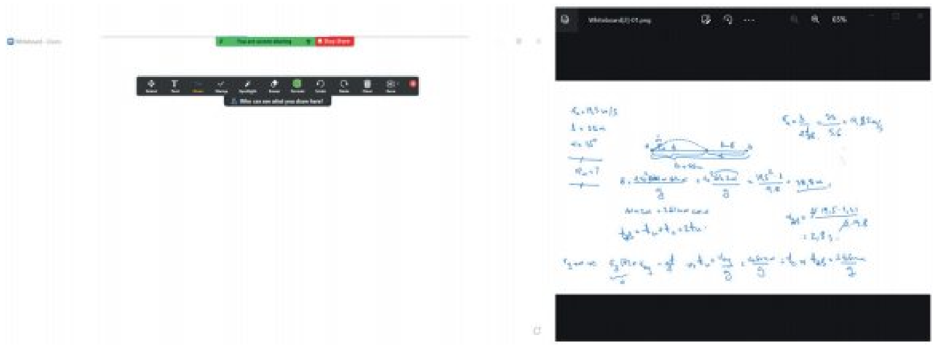


Figure 2.10. The whiteboard without and with graphics tablet

Students did not interact so well with faculty during seminar as if they were face to face. From this point of view, the seminars were not easy to organize. Also, laboratory activities were very difficult to sustain. Recordings were made in the laboratory (videos) with the installation of the equipment, the making of measurements, calculation of errors. Laboratory works in digital format, simulations (PhET Interactive Simulations), simulators, *YouTube* videos were used, which made the presence at the laboratory a very good one. A real disadvantage was that students did not gain technical skills when they watched films or use simulations, a fact emphasized even by the employers. There was a limited number of "open source" resources that were made available by various universities.

Another important aspect relative to the seminars and laboratories is that *Zoom* allowed the use of interactive applications like *Jamboard*, with the help of which the students could be consulted on certain problems, they also could work in a team or express different points of view. Also, menti.com allowed obtaining feedback from students relative to the understanding of a problem (for the *Zoom* basic version, menti replaced *Pool* from *Zoom*). *Padlet* might play the role of *Google Classroom* for *Zoom* users, allowing information to be organized for students. *Zoom* allows the use of other applications such as *Lumen5* (for making short videos) or for making posters (canva.com) and other advertising materials, so important in communication. There is a free version of all these applications, obviously the paid one is much more complex.

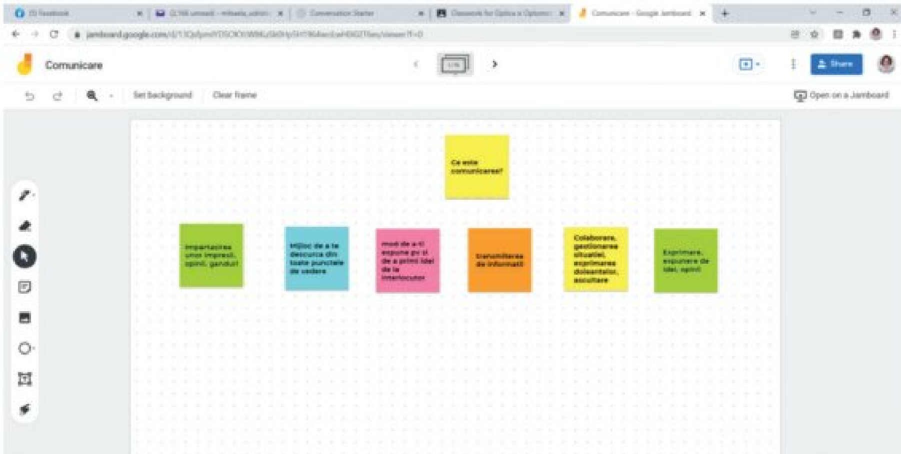


Figure 2.11. Example of print screen with using Jamboard application with Zoom

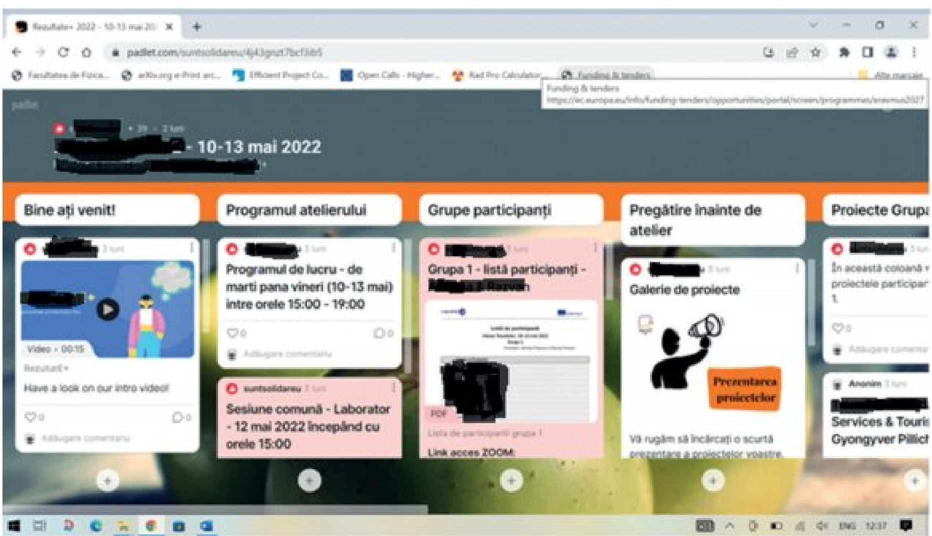


Figure 2.12. Example of print screen using Padlet application, complementary with Zoom

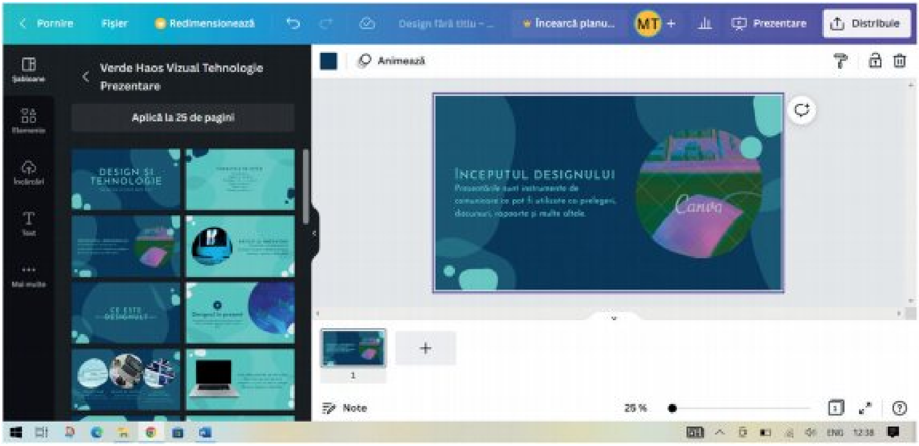


Figure 2.13. Example of print screen using Canva application to design different posters

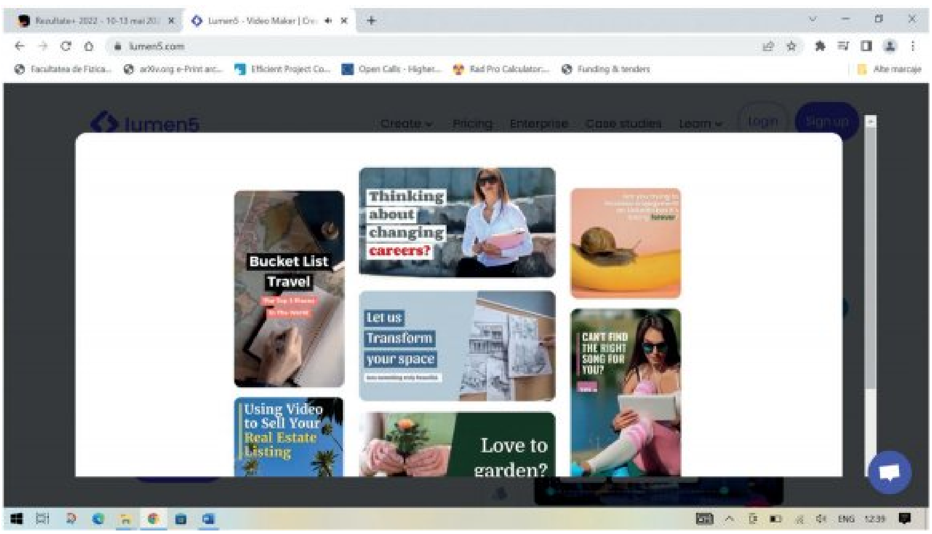


Figure 2.14. Example of print screen using Lumen5 application, especially for short videos

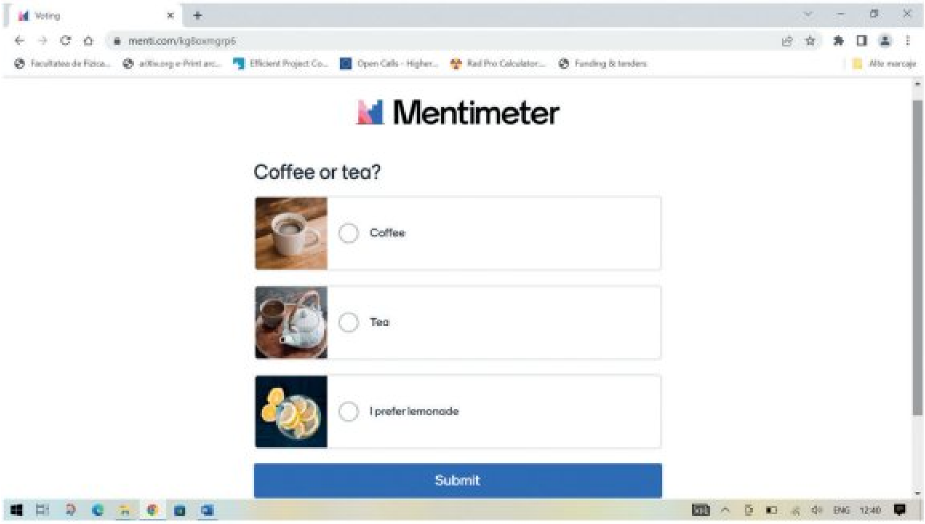


Figure 2.15. Example of print screen using Lumen5 application for interactivity

Indeed, anyone was not prepared for the impact of this pandemic crises. Even the UCv had *Webex* before pandemic, it was used only to organize senates and management meetings, online events (e.g. Faculty of Science Day, Researchers' Night). Webex was not used for the activities with students especially from financial reasons.

Sciences and Engineering Faculties involve carrying out laboratories or making experiments to fix the notions and concepts developed in the courses or seminars. Laboratory activities, at the beginning of pandemic, were affected or carried out partially or only demonstratively, without so much impact for the preparation of students, especially for those ones in the first year of the bachelor's degree. After the beginning of the academic year 2020/2021, graphic tablets were acquired to replace the physical blackboard and the professors who had classes, as a rule, used helpful graphic tablets. In addition, after the partial relaxation of the initial harsh conditions imposed by the COVID-19 pandemic, after we were able to arrive at the University (at the office/lecture hall/seminar/laboratory), some members of the faculty, with the help of a laptop and a high-resolution external camera, online teaching has started (demonstration lessons) directly from the lecture hall/seminar/laboratory. Even so, in the case of experimental subjects, students did not take measurements during experiment only analyse collected data, which did not solve the fundamental problem, acquiring technical skills by students. Students did not use the equipment to understand the assembly and functions of the collecting experimental data, errors, etc.

Progressively, and at the same time as the direct didactic activities carried out online, were related also on Zoom application activities such as:

- Tutoring and/or counselling activities;
- Additional or remedial activities, for students who could not participate in various activities;
- Consultations on the disciplines taught;
- Department meetings;
- Working sessions for different activities;
- Activities from projects with/for students, such as internship projects, projects to reduce dropout among students, volunteer projects with the involvement of teaching staff, students and some companies or partners, etc.;
- Local or national students' competitions;
- Events generated with or by employers;
- Taking the final exams of study programs (license, dissertation and postgraduate programs), in 2020 and 2021;
- Special events, such as graduation from the study program;
- Accreditation of study programs (even institutional accreditation) coordinated by the University of Craiova, with external evaluators, a process that involved to organize multiple, separate/disjoint online meetings with students, Faculty and potential employers, in one or more languages;
- School competitions, for students from high schools, (e.g., school Olympiads, national contests);
- A summer school, for disadvantaged students from high schools, with a duration of 2 weeks, in 2021;
- Courses for middle school and secondary education teachers;
- Conference for Physics teachers from middle schools and secondary education;
- Promotion of two volunteering projects or the educational offer of the Department of Physics and the Faculty of Science (promotion carried out in secondary education).
- International conferences.

Benefits, strengths, weaknesses. The advantage of *Zoom* was that we discovered an effective way of communication, when the direct interaction between people (in the current case, the educational sphere) moved to the online environment, with the total elimination of physical participation.

Distances were covered, people were connected, with some pluses and minuses for the education process. Certainly, we thus had at our disposal a very efficient tool, which allowed everyone to connect, regardless of device or operating system.

The ability to use *Zoom* tools would have been increased if the UCv had been involved in the training of human resources during the pandemic, through the Continuing Education Department or through Teacher Training Department, there are still many functions still unknown to some teaching staff. It is one of the lessons of pandemic, that human resource needs continuous training.

Some didactic or related activities could be recorded through the *Zoom* application and saved as a movie (e.g., in .mp4 format). Some courses, seminars or laboratories could be made available to students to be accessed later, which led to the creation of digital resources that could be used in other emergency situations. A way should be found for them to be stored and used further. The need for the existence of didactic materials in electronic format was seen in the pandemic. Even before the pandemic, there were universities (such as Duke University) that taught online, with students from all over the world.

Some activities carried out on *Zoom* were transmitted, for the purpose of promotion and information, on *Facebook* or *YouTube*, the *Zoom* application having the facility of interconnection with other applications (such as those previously mentioned). This increased the visibility of those activities in the online environment, it even contributed to a much better promotion/visibility of those activities.

In *Zoom* meetings it is very easy to share information through screen-sharing, during a course or seminar you can share, successively, from several participants, the screen of the device. In addition to the image, the sound can also be shared.

Using the application's *Chat*, files can be transferred to be accessed (saved) only by the participants in the meeting, and through *Breakout rooms* we can separate a meeting into groups, so that the participants from disjoint groups can communicate separately. On the chat there could be private conversations, which not everyone could see.

A major advantage of *Zoom* is that it has given to both, students and faculty, the chance to connect to some conferences where the fees were normally high.

From this point of view, students' involvement in research could increase. Also, prestigious universities (e.g., Oxford, Duke) organized a series of free courses (or with little money) during the pandemic.

Also, there are disadvantages of *Zoom*. For example, during the pandemic, sometimes the professors connected to several meetings simultaneously, because the programming was faulty. It was a lot of work which involved much more hours than usual, the degree of exhaustion being a significant one. All projects had to demonstrate the performance of the activity through *Zoom*. Sometimes, while carrying out the activity, the teaching staff could easily forget to release screenshots as well, which could later cause problems.

Another disadvantage is that the connection link could reach people from outside who entered the meeting and disturbed or could use the board. In other words, *Zoom* had some security issues, which were resolved along the way. One solution was that the intruders could be set to "mute", to stop the transmitted image or even be kicked out of the meeting, etc.

Sometimes, the *Zoom* customer service responded late, even if it was a paid Zoom warranty. Also, the *Zoom* server was connected to servers in China (especially on the conference application). Any delay in the meeting (related to connection problems) could lead to the non-connection of impatient participants.

Another *Zoom* advantage is that it allowed quite good service on poor quality connections. Thus, it made our work more flexible, more adapted to the needs of students. It brought us closer to the students. Students' participation in physical activities after the physical start of classes was not at the same level as during the pandemic. The hybrid version of the lessons proved difficult to achieve, because it is difficult to achieve the transmission of information to the video projector simultaneously with the *Zoom* transmission. Practically, there are important sound problems for those online when the video projector is used for those in the hall.

Hybrid version of some conferences are more difficult to organize but it reduced the costs of participating in the conferences giving the chance to participate for students and researchers from the whole world.

Why will we use Zoom post-pandemic? In the presented context, according to the new post-pandemic reality, the form of frequent education will allow the didactic and/or research activities to take place combined and successively, both in the university space and through resources/information technologies specific to synchronous online education, in a mixed organizational mode.

The mixed mode of organization thus involves the carrying out of learning, teaching and research activities "face to face", both in the university space, and by means of IT and communication resources and means, outside the university space. In the projection and programming of the activities, the observance of the principles of student-centred learning and teaching is considered with the capitalization of the outstanding progress in the field of information technologies, in order to develop innovative learning resources, methods and environments.

Learning resources can thus be more diverse, accessible, enriched in terms of how to approach the contents and the form of presentation, available at any time to students on IT platforms. Students can also participate in face-to-face activities and benefit from support from teaching staff and without moving to the university premises, thus increasing the flexibility of their academic journey and contributing to improving participation in tertiary education.

For individual study, students have permanent access to a secure IT platform, which allows access to the content of the course/seminar, in full or by study units, in digital format. Thus, students have at their disposal a variety of resources, such as: pre-recorded video courses, course notes in digital format, bibliography with digital access, specific databases, online documentation facilities, simulations, open educational resources (ORE) etc.

A series of national/international competitions that bring together participants from different cities/countries, might be organized free of charge using Zoom platform. Also, a series of meetings with employers, entrepreneurs, graduates can take place in online, on the Zoom platform. Such events can be streamed on YouTube or Facebook and will have a better visibility.

2.5. The use of Microsoft Teams platform in education (Miriam Spodniakova Pfefferova, Martin Hruska)

Microsoft (MS) Teams is another platform – next to Zoom, Webex, Google classroom, etc. – which became used more frequently during COVID-19 pandemic time. In the time before pandemic, MS Teams was used to much lesser extent than it is now, despite the fact that it provided many possibilities to make teaching more efficient and attractive. Just LMS Moodle was much more used system.

Although Moodle provides maximum support for distance learning – sufficient space for sharing materials, various information sources, and preparation of tools for obtaining feedback, at a time of many restrictions during the pandemic, it was necessary to start using a tool suitable for online teaching. Several suitable programs were already mentioned in previous parts. At the beginning of the pandemic time, faculty and students of UMB tried many of these programs. Finally, MS Teams was chosen as the only platform where the support of the university IT centre was provided (solving various problems, updates, etc.). One of the main reasons was the fact that MS Teams was part of the MS Office software package which is a common part of the software package for working computers at UMB, and there was no need to deal with the purchase of additional software.

Short description of the application. MS Teams is a cloud-based application that puts together the apps, conversations, meetings and files in one LMS. In addition to this, the use of MS Teams has improved the process of teaching-learning, the ability of the faculty to grade and monitor the learners' activities and assignments, as well as the classroom organization and the teacher-student interaction. Courses using Teams can be 100 % online, hybrid, or face-to-face. This tool enables a wider range of teacher and student interactions and allows for regular, substantive interaction in online courses (Poston, Apostel & Richardson, 2019). Some of the features in MS Teams are: chats, group features which is known as "teams" with 2 types of channels: general and private, assignments, class notebooks, files, test and meeting (a feature which is similar to video calling but in bigger groups) (Juanis, 2020).

Most of the activity in the application is focused on working in "teams". By team we mean a logical grouping of users, which is determined by their social role in the organization (at school). Teams are made up of employees, company management, students belonging to a specific class/course, project participants, students and faculty in the interest group. It is therefore a logical (virtual) grouping of people with a common interest or position in the school environment (Microsoft Teams, 2022).

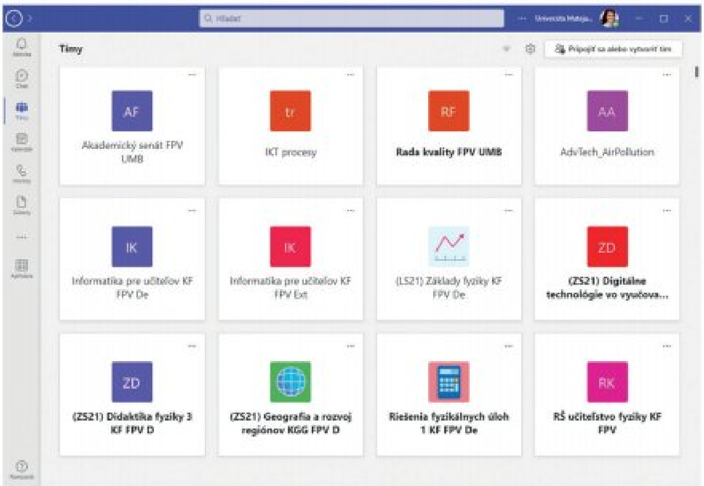


Figure 2.17. A sample of MS Teams desktop app with various teams (teams for educational courses, a team for online communication with university IT support, a communication canal for project team, etc.)

Teams can be established by users themselves who have sufficient rights set up for this action in the network from the owner, the network administrator. Within the teams, the own communication takes place in the so-called channels. A channel is an association of a topic-related conversation with other activities that may be related to the topic, such as file sharing, OneNote notebooks, Planner timelines, Forms, or other applications that can be added to the channel as additional cards.

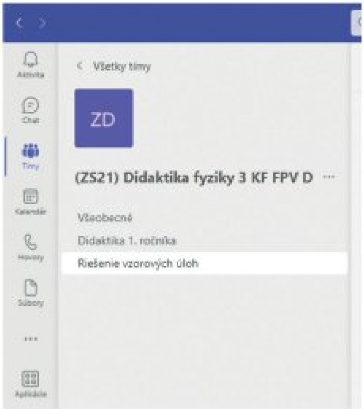


Figure 2.18. A sample of more channels for the different topics of conversation

The Teams application is available for various operating system platforms (Windows, iOS, MacOS, Android) or as a web application. The developers try to maintain the same consistency of control and layout of the application controls on most platforms. Only the mobile version of the application and the desktop version differ significantly from each other (Šindlerová, 2018)

MS Teams for school practice. MS Teams can be used for various purposes, but we will focus on its use in the teaching process. MS Teams has many functions and additional applications which are interested just for education (Meet Microsoft Teams, 2022):

- manage learning using conversation or input functions;
- in the "point a finger" conversation - mention a specific user or group of users with the @ sign;
- send private messages to users;
- conduct video calls with individuals or groups (suitable for distance learning);
- easily share files with other users;
- edit one file by multiple users in real time;
- give pupils "assignments" – tasks which are then easily submitted and evaluated by the teacher;
- use either a point scale or a verbal assessment or an assessment using criteria to assess students;
- create custom applications based on the PowerApps platform tailored to the school's needs and integrate them into the Teams environment.

The pandemic has taught us to use many tools, such as MS Teams, which were previously overlooked, or were not given much importance. After two years (2020, 2021) of online teaching, we can state, based on the various results of the conducted surveys, that MS Teams has a positive impact on education (Khidir, Sa'ari, Mohammad, 2021) (Juanis, 2020):

- helping interaction between students or between students and teacher,
- increasing learning motivation,
- assisting in learning more effectively, etc.

Like everything, using MS Teams has its advantages and disadvantages (e.g. not very user-friendly environment for the first using, limited functions of applications integrated into MS Teams). Despite the disadvantages, the use of MS Teams brings a lot of positive effects on teaching, so it is reasonable to think that MS Teams will remain part of the teaching process even during face-to-face teaching.

2.6. DIPSEIL system at Plovdiv University (Diana Stoyanova)

Distributed Internet-based Performance Support Environment for Individualized Learning (DIPSEIL) is a learning management system (LMS) that is developed by a team of PU "Paisii Hilendarski". The learning content in DIPSEIL is based on learning tasks. Learning tasks are aimed at solving specific problems. In the process of their solving, the student acquires the necessary knowledge and skills in the relevant discipline [1]. For each learning task, the teacher provides:

- Task description (Task description) - contains an explanation of what the student must complete and in what time frame.
- Specific theoretical material (Task-specific training) - contains the necessary theory that the student must learn in order to complete the task.
- Reference information (Reference information) - technical diagrams, reference materials, books, WEB links, etc.
- Instructions for performance (Instructions on how to perform) - guidelines for performance of the task.
- Expert advice - information about possible problems, symptoms, and solutions for all critical situations.

Students perform the learning tasks throughout the semester and collect points for each learning tasks performance.

DIPSEIL consists of two modules:

1. DIPSEIL Teacher Area - environment where the teacher can create a new course, add new modules and learning tasks, edit courses, modules and learning tasks, access students' solutions (Fig. 2.19).

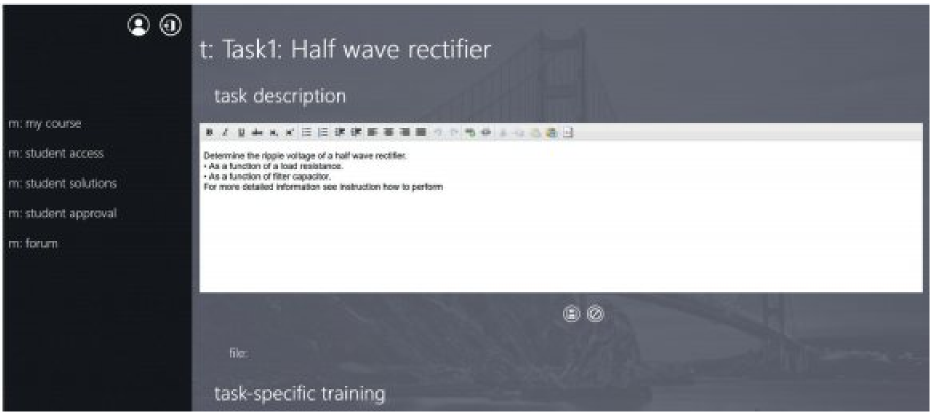


Figure 2.19. Editing a learning task in DIPSEIL Teacher Area

2. DIPSEIL Student Area –environment where the learner can perform the learning tasks and submit their solutions (Fig. 2.20)

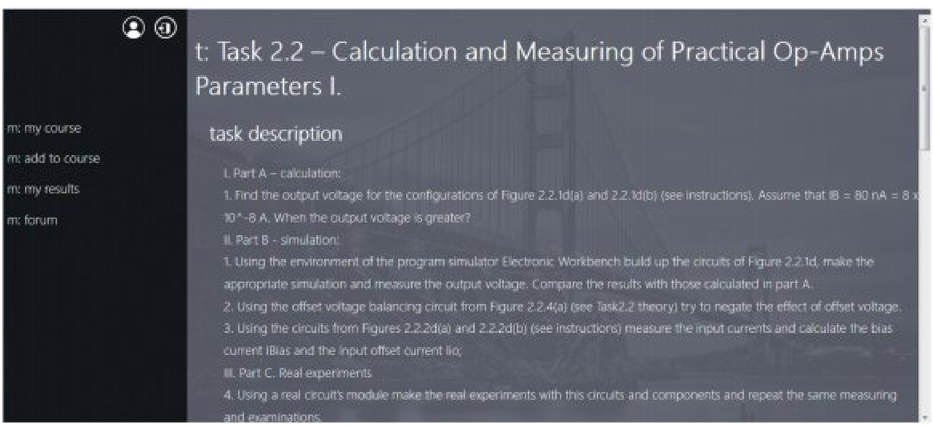


Figure 2.20. Access to learning tasks description in DIPSEIL Student Area

The module Forum in DIPSEIL enables asynchronous communication between students and faculty. The discussion in the forum is at the learning task level. Our long-term experience in using DIPSEIL shows that performance support learning environment is extremely suitable in engineering education because through it students not only acquire theoretical knowledge but also learn to solve real-life problems.

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CHAPTER 3

THE ROLE OF INTEGRATIVE APPROACH IN THE TEACHING AND LEARNING OF STUDENTS IN STEM SPECIALTIES AT THE UNIVERSITIES

In recent decades, the integration processes in science and social practice increasingly actively influence the development trends in the field of the educational process. The global problems of modernity have an integrating effect on humanity, which is aware of interrelationships and interdependence, the community of nature and social phenomena. Integrative trends are increasingly singled out as specific ways to improve the structuring of learning content to help future scientists and engineers make more holistic sense of the studied objects and phenomena and differentiated conceptual structures.

The nature of engineering education implies a high level of fundamental training and of specialized knowledge and experience consistent with the requirements of professional guilds. Thus, the dynamics in the learning goals of natural sciences and engineering are provoked by the objective processes of professional practices and are a reflection of different levels of integration. This integration is a consequence of the globalization of production and the diversity of products and goods. As a result of studies in natural sciences and engineering, students are required to have developed creative thinking in interdisciplinary contexts and to be able to conduct adequate communication on a range of scientific, technical and technological issues in line with increasing complexity of technical systems and new, constantly developing markets.

The International Society for Engineering Pedagogy (IGIP) defines the development of engineering education in the following directions:

- Improvement of teaching methods depending on the development of new SMART technologies;
- Development of practically oriented programs corresponding to the needs of students and employers;
- Integration of language and humanitarian education;
- Acquisition of new competences in the field of communication skills, teamwork, ethical and intercultural competences.

Addressing the issue of an integrative approach to STEM education in universities is important, broad enough, and suitable for serious research. Here our aim is only to present the experience of a few universities (UCv, ATU, PU, UMB) related to this topic.

The main goal of integration in education is building a comprehensive picture of the world, development of students' worldview in intensive correlation with the environment, quality professional training and strengthening of emotional experiences (Andreev, 1986).

In the pedagogical aspect, the integration of education has its foundations in the paradigm of holism. In it, reality is seen as an integrated whole, and not as a collection of disparate elements and fragments. The integration helps to avoid the expansion of the learning content and solve the problem of learning overload to some extent.

While in the middle of the 20th century ideas of integration are manifested as intersubjective connections, in modern science integration is at the level of synergy. As a transdisciplinary scientific theory of self-organization and organization of complex dynamic processes, it leads to a vision of the universality of the world and ensures the dialogue of natural sciences and humanitarian culture. The systematic approach in scientific knowledge is always carried out in interconnected processes of differentiation and integration, which are related to a mathematical unity of the world.

Integrative learning is a realization of the integrative approach, which represents the way, the way to implement integration. On this basis, training is organized, viewed as a system and as a process of establishing integrative connections.

3.1. Forms of integration and ways to implement the integrative approach in education (Zhelyazka Raykova)

There are different **forms of integration**:

- organizational, which shapes and strengthens the creation of learning complexes, educational network, etc.), as a unity of education;
- the educational content, which is related to the integration of the content of various educational subjects in the context of solving life problems;
- of concepts, technologies and teaching methods Gritsenko L.I. (2012).

Structural and functional integrative tendencies are distinguished. Structural ones are related to the nature of scientific knowledge and the degree of generality and abstractness. It is related to the integrated (interdisciplinary) courses. Functional integration is the centring of learning content around an important principle, idea, or theme. The topic-oriented approach is the most frequently presented for qualitative integration. This also includes work on projects (diploma theses), which include knowledge from different subject and subject areas.

In pedagogy, two more types of integration are distinguished - horizontal and vertical *according to the continuity* of educational knowledge. Vertical integration ensures continuity between studies at different educational levels – between secondary education, bachelor's degree and master's degree.

One of the most applied ways to implement integration is the implementation of **interdisciplinary training.** Interdisciplinary learning develops as a deliberate attempt to apply knowledge, principles, and/or values of more than one academic discipline simultaneously. Academic disciplines may be linked by a major theme, question, problem or practice.

In interdisciplinary integration, learning is organized around common themes for several sciences and academic disciplines. Her teaching begins with the formulation of a real-world problem and focuses on interdisciplinary content and the formation of general curricular skills (e.g., critical thinking and problem-solving skills). Thus, the concepts and skills of individual disciplines become interconnected and interdependent, and the boundaries between the disciplines begin to blur. Students are encouraged to realize the application of the disciplines and the significant role of social interactions in analysing problems. The structure of interdisciplinary learning is consistent with the main characteristics of deep learning, where the learner is expected to actively participate in the process.

Effective interdisciplinary learning can be *individual, within project assignments or in longer integrated courses of study*, and must meet the following requirements:

- have clearly planned goals;
- to be based on experience and learning outcomes in different learning areas;
- to provide progress in skills, knowledge and understanding;
- to provide learning opportunities at different levels in different areas that are integrated into the set learning tasks [IGIP].

What are the **training methods** for implementing the integrative approach in training?

Since the integrative trends are dynamic and functional, combined with a great mobility of didactic phenomena, they also imply a great variety of methods with the help of which training is realized.

Many **traditional methods** have the potential to meet the requirements of this approach if they meet the condition of contributing to the full expression and realization of integrative trends in education. There are also those of priority importance and they are related to the activation of the overall participation of learners in the learning process.

Modern methods, or more precisely, those that take on a modern appearance with the widespread entry of information technologies into life, attract more and more followers among educators and researchers. Some of them play a leading role in the implementation of the integrative approach.

The tasks of integrative learning are solved most successfully when the learning is implemented along the path of discovery, i.e., using the **research method**. This method is an important part of inquiry-based learning that builds new knowledge.

The application of the project method and its variety, **project-based learning** is a method that acquires a modern appearance through the application of information technologies. The project activity, by its very nature, is aimed at the united achievement of a certain, clearly set goal. The main elements of any project are – activity, integration and purpose. The projects are related to the life interests of the students and the application of this method makes the knowledge whole, unified and integral (Andreev, 1986). This is possible when the boundaries between individual subjects are crossed and integration in learning takes place.

The use of the integrative approach is also related to the application of the **problem-oriented method** (problem-based learning). It is based on inductive or deductive evidence, requires processing of the learned information in order to obtain new information and solve the problem. The integrative trends here are contained not only in the subject knowledge and skills, but also in the general academic skills that are important for the personal growth of the students.

With the methods listed above, it is important to emphasize that they are predominantly **practical in orientation**. This allows students to carry out experimental work, work in the field, analyse collected data, explain and predict.

The realization of integrative tendencies requires the implementation of **cooperative (joint) learning**. It is structured through **teamwork**. Working together, students receive informal training in social skills and become convinced that human knowledge is produced by many scientists from different fields, through joint activity and collaboration.

All these methods are based on constructivist ideas, and each one of them has different opportunities and limitations in the process of integrating learning. Teaching methods are dynamic and constantly repeated in accordance with the development of society and technology, and therefore it is not appropriate to seek and justify any correlation between them.

What are **the reasons** that determine the need to implement the integrated approach in STEM education in higher schools?

- Need for integrated training for the fronts of science.
- The growth of world interconnectedness (globalization), global problems and our obligations to find the right solutions require a direct connection of education with global issues.
- Environmental issues, which are gaining more and more global importance and have a strong social resonance, have their place in the education of science and engineering specialties. As a result of this integration and on its basis, the work on the project "Applying some advanced technologies in teaching and research, in relation to air pollution" was organized.
- The freedom of students to choose subjects that are relevant to their interests and the need to reduce the number of academic disciplines at each stage of teaching. The boundaries of the various academic disciplines in the field of STEM are changing and new ones are emerging. The integrative approach in science increases the transformation of teaching, i.e. students more easily notice the internal relationship between concepts, principles and concepts, because the idea is followed that the structure of knowledge reflects the structure of the individual science.

- The integrative approach enables different scientists to plan and teach together, increases cooperation between them, strengthens the connection between knowledge obtained in life and in higher education Raikova, Zh. (2019).

The following can be mentioned as **basic ideas** in STEM education that provide integrated learning:

- Training should have a *vital character*. The process of studying STEM subjects should not only be a preparation for life, future realization or profession, but should be a full experience for every student.
- Education in physics and in engineering specialties should be *active*. Integrative trends in physics education should be seen in the context of constructivist ideas. The main premise of constructivism is that the integration of knowledge is not passively accepted but develops as students construct their own knowledge. Learning through activities is a major component of constructivist theory. It is important that spontaneous activity is leading, and not determined by external prompts and stimuli. The idea of activity is related to self-study *and group work*. The activity of the students has a real educational and educational result only if they are busy solving their own problems and satisfying their own interests.

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Actualization of Integrated STEM Degree Programs: A Model to Inform, Catalyze, and Shape Inter- and Trans-Disciplinary University Education APEC Human Resources Development Working Group September 2021

3.2. Integrative trends in the education of STEM students at the four universities participating in the project (Zhelyazka Raykova, Mihaela Tinca Udristioiu, Ece Yilmaz, Janka Raganova, Yunus Çelik, Hasan Yildizhan)

The experience of the four universities participating in the project is systematized in the following aspects:

- **Formal integration:**
  - The inclusion in the curricula of study disciplines that allow integrative learning and the formation of modern competences.
  - Conducting classes together with specialists from fields that are not specific to the students' professional training.
  - Carrying out common initiatives with different specialists from different fields.
- **Content integration:**
  - Inclusion of the learning content of some specific professionally oriented learning disciplines, knowledge from another science or another scientific field.
  - Work on integrative projects.

FORMAL INTEGRATION

- ***Inclusion in the curricula of disciplines that allow integration***

At the **UCv**, **Department of Physics**, the facultative subjects at Bachelor programs (Computational Physics and Medical Physics) are History of Physics, Programming concepts for physicists, Foreign language (French and English), Oscillations and waves, Data acquisition and processing systems, Astrophysics and cosmology, Transmission of information through optical fiber, Biochemistry. At master programs there are not facultative subjects in curriculum.

Foreign languages are important for students because both master programs (Theoretical Physics, Applied Physics) are in English. The most important part of the scientific literature is in English, so students should improve their skills in foreign languages. Romania is a francophone country and from this reason there are many students who want a study experience in France. Also, there are international events for students in English (summer schools, conferences, seminars). They should be able to communicate in a foreign language because is the key of comprehension and communication. Another aspect is that each university needs internationalization, relations with other universities, exchange of experience and good practices, projects research. In the framework of the Erasmus+ cooperation, there are mobilities for students and academic staff, projects which are conducted in foreign languages.

Programming concepts for physicists, Data acquisition and processing systems are important for students to handle data provided by measurements during lab activities and to program sensors developed on Arduino or Raspberry PI during Electronics laboratories.

There is a company (Prysmian Group) in Oltenia region focused on the production of optical fibre and for this reason there is a course in this field. They need graduates who understand how can be made quality assurance for optical fibre. In Craiova, there are 25 companies and firms that activate in ICT and they need heigh skilled graduates in programming. At the request of the companies were added subjects in this field.

History of Physics is necessary for students to understand how evolved the knowledge in Physics, which is the role theory and experiment in knowledge, to understand the nature from physical point of view.

The aim of the course of Oscillations and waves is to help students to understand how an oscillation propagates in a free space or in a material environment. Students should understand the features of waves. Medical physics graduates might work in an environment with ionizing radiation and it is important for them to understand the duality wave-particle for X and gamma radiation, electrons, protons, etc. Also, there is a postgraduate course in Acoustic and Audiology and this course helps students to find out job in another niche filed, audiology.

There is a successful course in Celestial Mechanics for Physics and Mathematics students, in the third year of the bachelor program. It is a good combination of knowledge for both programmes. At UCV, there are telescopes and a planetarium for practical activities.

At **ATU, Department of Engineering,** the facultative subjects in the Bachelor programs are Tourism Geography of Turkey, Introduction to Economics, World Economy, Introduction to MatLab for Engineers, Organizational Behaviour, English for Academic Purposes, Mining History, Environmental Problem, History of Science, Strategic Management, Management, and Organization. In master's programs, there are no facultative subjects in the curriculum.

The British Council has designated the university as one of five pilot universities in Turkey for the "Program for Improving the Quality of English Education in Higher Education" established for higher education institutions. Furthermore, it offers an English education that is accredited by "Pearson Assured," ensuring excellence. Except for a few disciplines, ATU offers a completely English-based education. As a result, many departments have international faculty members.

As a result, English instruction is critical for ATU students. Furthermore, because the programs are offered in English, many students are interested in participating in international exchange programs. In addition, other English activities are carried out by student clubs at the university. Members of the club, for example, plan speaking club activities. Various organizations are also held with the participation of Erasmus students. Such exercises are extremely beneficial to students' foreign language development. It should also be highlighted that student and academic mobility from the Erasmus+ programs are extremely important and beneficial at this time.

For engineering students, the history of science and programming such as MatLab is very important. In addition, the fact that there are courses in social sciences in the curriculum gives students a multidisciplinary perspective. It provides very useful information for engineers who will take on managerial positions in the future. In addition, the provision of an academic English course is very important in terms of improving the academic English level of the students. Thus, if students want to advance in the academic field in the future, they will have formed their foundations. The history of science is necessary for students to understand how knowledge develops, the role of theory and experimentation, and how science has evolved from past to present.

The need for people who know to program in today's conditions has been a pioneer in adding Matlab to the university curriculum as a course. Since Matlab is a very important and used programming type in all engineering departments, it is seen as a sought-after skill in today's employment.

In the **Faculty of Physics and Technology (FPT) of PU**, students study optional subjects, which, according to the requirements of the National Accreditation Agency of Bulgaria, must be 4 % of the total number of subjects (about 90 hours). Students choose and study three of the optional subjects during their undergraduate studies. These academic disciplines must be different in content from those that are closely related to vocational training.

The ones for the physics majors (Engineering Physics, Eco-energy Technologies, Medical Physics and Technologies in Telecommunications) are: Specialized English Language, Foreign Language - Russian, German, Economics, Business Communications, Human Resource Management, Creativity, Responsibility and Leadership, Technical Safety, Economics of Technical Change, Innovation and Entrepreneurship, Biomedical Ethics, Psychology, Technical Documentation with AutoCad.

For the engineering majors (Information and Computer Engineering, Telecommunications and Information Technologies, Telecommunications with Management) the optional disciplines are: Specialized English, Foreign Language, Business Communications, Economics of Technical Change, Innovations and Entrepreneurship, Marketing Studies, The New Times in Europe: scientific, applied and social ideas, Sociology of science and technology, Sociology of traditional and modern societies, Contemporary risk societies: a sociological analysis, Introduction to psychoanalysis, Technical English, Presentation and communication skills, Technical safety.

Learning foreign languages is important for future specialists who graduate from the faculty. A good command of the English language provides them with opportunities to continue their education in master's programs in English, both at FPT and around the world. Their potential opportunities for their participation in Erasmus international student exchange programs also require a good command of the language, as well as the formation of technical and scientific documentation (articles, participation in international conferences, etc.). Finding a job in the specialty in the many international companies in Bulgaria is also a motivating factor to learn foreign languages.

The inclusion of economic disciplines (Economics, Business Communications, Human Resource Management, Creativity, Responsibility and Leadership, Technical Safety, Economics of Technical Change, Innovation and Entrepreneurship) in the curriculum allows students to gain knowledge that will expand their preparation for the real conditions in both industry and business.

The economic, financial and managerial literacy of students, future physicists and engineers is a condition for the formation of important key competences such as "Civil and public competence", "Initiative and entrepreneurship". The other academic disciplines are directly related to the personal growth of the students - "Independence and responsibility", "Personal and social competences and learning competence", "Presentation and communication skills". The inclusion of disciplines with social content such as "The New Time in Europe: Scientific, Applied and Social Ideas", "Sociology of Science and Technology", "Sociology of Traditional and Modern Societies", "Contemporary Risk Societies: Sociological Analysis" complement the general educational preparation of students and create the integrative nature of learning.

The Faculty of Natural Sciences, UMB provides two kinds of study programmes. First of all, it has a long tradition in preparing teachers for primary and secondary schools in the field of natural sciences (Biology, Chemistry, Physics, Geography), Technology, Mathematics and Computer Science. Nowadays, the faculty also offers non-teaching study programmes, for example Environmental Biolology, Forensic and Criminalistic Chemistry, Applied Computer Science and Software Development, Geopotential of Regions, Mathematics of Data Analysis and Finance, Applied Geosciences, Geochemistry (Ph.D. study programme) etc. The integrative approaches are applied in the both kinds (teacher training and non-teaching) study programmes.

First, the character of some of the programmes itself is integrative. For example, the Environmental Biology integrates knowledge and methods of environmental science and biology. This study programme is therefore providing by two departments: Department of Biology and Ecology and Department of Environmental Management. Geochemistry integrates two fields of the nature study: geology and chemistry. Another example is Data analysis and Finance study programme that integrates knowledge of one of the STEM branches with studies of economics.

Although the system of science teacher training follows the separate way of teaching of sciences (Biology, Chemistry, Physics) at primary and secondary schools in Slovakia, the integrative approaches can be found also in the teacher training programmes. Physics is considered the basis of all other natural sciences; thus, physics lessons form a part of curricula of Biology a Chemistry study programmes. And vice versa: students of physics can gain knowledge of chemistry within a special course arranged just for them.

In addition, all students of the Faculty of Natural Sciences have an opportunity to profile themselves by selecting courses that are provided by any department within the faculty or even within the University. No doubt that the most popular courses are provided by the Department of Physical Education and Sports of the Faculty of Arts. Thus, the University supports both intellectual and physical development of students and outlines an importance of physical activities to students of all branches.

Moreover, the Faculty of Natural Sciences provides a set of optional courses for students at all study levels (bachelor, master, PhD) that aim to develop student general knowledge, soft skills and life competences. At the bachelor level such courses include, for example, courses dedicated to the development of mathematical or English language skills of students, to the development of their financial literacy, management and communication skills etc. A special attention is given to a development of student skills to use digital technologies first as effective tools in the learning process, later as a tool supporting research. Several optional courses are focused on environmental issues: Global environmental problems, Biodiversity – news in its protection, Earth's ecological system and its present changes etc. Students can also gain knowledge of rational nutrition, first aid and prevention of drug addiction. A very important group of optional courses consists of courses that aim to educate students – future researchers and STEM specialists – in the methods of gaining and processing experimental data and to develop their skills necessary to conduct independent research projects: Elementary statistics and probability, Algorithms and programming for non-computer specialists, Selected methods of measurement and analysis data in the natural sciences (FPV UMB, 2022).

The last-mentioned course was included into the set of the optional courses provided by the Faculty of Natural Sciences UMB as a result of the international Erasmus+ project AdvTech_AirPollution. The course is focused on an introduction how to collect data with the use of sensors based on microcontrollers. Students have a chance to participate at the summer school organised by UCv and to gain practical skills and experience in designing, building and programming the sensors, as well as to gain an insight how to process the data given by sensors (Udristioiu, 2022).

The optional courses that are offered to students at magister level enable students to gain knowledge and skills either in a specific scientific area or in a general topic important to students of all study programmes, such as statistics, ethics and methodology of research etc (FPV UMB, 2022). Some courses focus on the use of advanced technologies in science – Virtual technologies in Geography, The use of microcontrollers in education, Molecular modelling and other.

As examples of magister voluntary courses that are built upon integrative approaches, we can mention three courses: The first one is a very popular course "Myths and superstitions in natural sciences" that has aimed to develop student critical thinking in connection with typical myths, superstitions, hoaxes and misconceptions in the natural sciences. The intention of the course is to increase students' ability to apply critical thinking and knowledge of natural sciences to everyday life. Thanks to a series of interactive lectures focused on the discussion of selected myths in the field of natural sciences, students can identify reliable sources of information, to test the presented solutions critically and to argue to support their positions and attitudes. The discussed themes and topics have included for example research failures (thalidomide and others), homeopathy, vitamin C, miracle drugs without a prescription, natural = safe, glutamate. Students also work with interesting myths of the Internet environment such as "healthy" nutrition, miracle diet etc. (Budzák, 2022).

Another optional course popular especially among students of Physics, Chemistry and Biology is the course Integrated science through experiments. The course was incorporated into study plans at the Faculty of Natural Sciences as a result of an effort to encourage the application of a more integrated approach to the sciences and to provide students of physics, biology and chemistry a greater understanding of natural phenomena. The teaching and learning materials used within the course include integration of science curricula in two meanings: an integration of knowledge and methodology of physics, chemistry and biology, as well as an integration of various real and virtual computerised methods of experiments. Student learn doing investigative activities, in which they can study life science processes using computerised data-logging tools. The themes were chosen to illustrate the integration of natural processes and cover topics such as Origin and development of the universe, ordered universe, Energy, Colours of nature and colour vision, Imaging technologies, Chemical bonding, Carbon in non-living and living nature, Life, molecules of life, Cells, nature and diversity of cells, Classical and modern genetics, Earth and other planets, solar system, evolution, Earth dynamics and earth cycles, Ecosystems, radiation in everyday life, thermoregulation in living organisms, environmental measurements, etc. (Holec et al., 2004).

An integrative course with a title Advanced technologies to process big data in science was incorporated into curricula at the Faculty of Natural Sciences in academic year 2022/2023 as a result of an international cooperation of four partner countries within the AdvTech_AirPollution Project. The course enables students to obtain a comprehensive overview of data analysis methods and approaches and the field of big data. After completing the course, the student will be able to choose and use the right tools for processing a data analysis, interpret the achieved results and evaluate their reliability (Duda, 2022). The students will be trained to process the data with the use of data sets from sensors monitoring air pollution. Therefor besides the digital skills students will develop also green and STEM competences, so required by the research and industry (Udristioiu, 2021).

- ***Conducting classes with specialists from areas that are not specific to the professional training of students***

Once or twice per month, each department of the **UCv** has organized meetings with graduates and professional models in career. These meetings represent a bridge between generations that makes easier the exchange of experience between students and graduates. Debates and presentation on topical issues like green energy (nuclear fusion and fission, solar and wind energy), laser applications, plasma, refractive issues, colour, and electronics were organized. Professors from Optometry are invited to give lectures and presentations, Optometry being a niche field where our students can find easier a job. Specialists from Radiotherapy and Nuclear Medicine to give presentations for Medical Physics students or teach different subjects to the students from the postgraduate course in Radiotherapy for Medical Physicists. Practice from Optometry and Radiotherapy is made only with specialists from these fields. Associate researchers from climate change, weather and environment help students to understand why adaptation and mitigation for climate change are so important for each community. The purpose of these meetings is to help students to find out fields where they might work after graduation and to help them to think “out of the box”. Their exposure at different ideas and concepts contributes to the development of their multidisciplinary and open thinking.

Also, there are organized meetings with employers where can participate trainers, PR specialists, engineers, experts in different fields from different companies and firms (in Optometry, Radiotherapy, Nuclear Medicine, Medical Imaging, ICT). Students can find out genuine information about potential jobs, employers’ expectations, internships, projects that will be developed in next years at companies. Students visit local companies to appreciate if they want to work or to have an internship there. It is part of their orientation program.

Additional, students' sessions of scientific communication are organized each year and students can present their fields of interest. At these sessions, students from all faculties can participate. Students from Science Faculty participate to the sessions organized by environment branches from Engineering or Horticulture and Agriculture.

Moreover, the UCv has a research infrastructure in Applied Sciences and bachelor and master students can apply for scholarships. Some of the PhD students work there, taking measurements and analysing data in those modern research laboratories. Incesa hub is well connected to the needs of the local companies, developing together some research projects. Bachelor and master students visit this infrastructure once or twice during their academic program.

At **ATU,** academicians from other faculties who are experts in their fields or people with certain experiences in the sector are selected to give elective courses to our students. At this point, the selection criterion is that the individual is competent in his field. Professional knowledge and experience are considered. It is for preferring competent people and transferring healthier and more effective information to students. People who have experience in the subject area for many years have sufficient knowledge to deal with the relevant subject at many points. In addition, students can visit and use the laboratories of other departments if needed. In addition, the career centre of our university regularly hosts important names from the sector and organizes seminars every week. This seminar is held on Instagram. The purpose of this is to broaden the perspective of students from all departments by participating in such activities. In addition, various training is organized by inviting people from the sector to the university, and students who wish can participate in these activities by making an announcement to each faculty.

Organizing such activities is very important for the development of students toward business life. Students can get answers to the information they have learned theoretically and to which degree they are used in the sector. It is very useful in terms of learning what awaits them in the sector after graduation. In addition, in these events, authorized persons explain the job and internship opportunities of their companies. There are also students who do their internships through these events. Based on this, it can be stated that these activities provide positive results for students in many respects.

Events related to some of the 9 faculties of the university are held almost every day at **the PU**, in which all students of the university have the right to participate. In the auditoriums of the university, many and varied meetings are held with famous personalities of the day - from ambassadors to prominent scientists, authors of books or prominent athletes, artists, etc. Given the location of Faculty of Physics and Technology (FPT), whose laboratories and classrooms are in the central building of the university, information about these events is available to our students and they benefit from this convenience.

The dean's management of the FPT has organized meetings with representatives of large companies that deal with human resources and finding a job. Training is also organized for students on what are the requirements for conducting job interviews or preparing documents, etc. taking advantage of the practical experience of specialists in this field.

The classes of some of the disciplines of the specialty "Medical Physics" are held at the Medical University in Plovdiv. Students conduct practical classes in operating imaging laboratories together with future doctors. Communicating in the field with specialists from this field is extremely useful for their professional training. Taking them out of university classrooms and laboratories, where classes are traditionally held, increases students' interest in their major, gives them the opportunity to compare with students from other higher education institutions, and motivates them to study more consciously.

At **UMB**, we believe that an understanding of interrelationships and interactions in different fields stimulates the development of the student personality. It is also important to provide students a chance to think in broader contexts, do not leave them to live in a "bubble", far away from a real society.

Therefor we encourage students to visit lectures and workshops given by the specialists from various fields outside the Faculty of Natural Sciences, such as economists, technical experts, specialists in pedagogy etc. These specialists very often come from other regions in Slovakia, from the Slovak Academy of Sciences or from foreign universities.

We also organise excursion for our students to various organisations where our students could work after their studies, such as Slovak Environment Agency, Slovak Academy of Sciences, various private companies and NGOs, Town hall, Slovak Hydrometeorological Institute, Banská Bystrica Astronomical Observatory etc.

- ***Conducting joint initiatives with different specialists from different fields***

During pandemic, some conferences were online and without taxes, students having the chance to participate. It was an opportunity for some students, who are interested in research, to collaborate and even publish together with their mentors. Students made measurements, collected data in our labs, together with specialists, and analyse together. Such students become independent in their work and learn how to write a paper.

At the **UCv** have collaboration on Medical Physics with students from the Medicine and Pharmacy University and on Environment with students and academic staff from Horticulture, Agriculture and Electric Engineering Faculties. Moreover, students were invited to participate to some conferences, workshops and summer schools organized by some professional associations (SEENET-MTP, EFOMP, CFMR). It is a chance for students to know students from different countries, cultures and faculties. These experiences make students more flexible, develop their communication in foreign languages and to listen or work with international specialists.

Many seminars and conferences are organized within the **ATU, Turkey**. The Career Centre unit, which is responsible for such activities, organizes many different and comprehensive conferences and seminars for students in many fields, announces these events throughout the university, and offers all students the opportunity to participate. The events held during the pandemic period were held online through platforms such as Instagram, Zoom, and Google Meets. It is aimed to reach students from every department, especially by trying to realize it through Instagram. After the pandemic, online training and conferences continue, and in addition, many face-to-face events have begun to be organized. In addition, students or academics from many different fields can find the opportunity to be involved in projects or research carried out at ATU. Students from different departments are sent to the Erasmus projects carried out. In addition, academicians from the faculty of engineering, faculty of business, and foreign languages are involved in current projects.

Students of the **Faculty of Natural Sciences UMB** have an opportunity to work in specialised laboratories of important business companies, such as Continental Slovensko, IBM, and metal factory in Podbrezova etc. A very important is also an international cooperation with universities under Erasmus+ programme. Students from the Department of Computer Science visit, for example, specialised laboratories of Oulu University of Applied Sciences in Finland. PhD students conduct their research also in labs at Slovak Academy of Science and visit partner universities, for example in France.

Students from the Faculty of Natural Sciences UMB have a chance to participate at the research projects conducting by researchers and departments of the faculty, financed by national grant agencies. Students are also encouraged to participate at a student scientific conference that we co-organize with our partner Constantine the Philosopher University in Nitra. Students present results of their research work and compete of the best student research project. Such student conferences are organised at international level with partner universities in the Czech Republic in some science fields. Students can also present their results at scientific conferences in Slovakia and abroad, such as Didinfo (http://www.didinfo.net/), Informatics (https://informatics.kpi.fei. tuke.sk/), Information and Digital Technologies (https://idt.fri.uniza.sk/) or Conference for young hydrologists organized by Slovak Hydrometeorological Institute.

CONTENT INTEGRATION

- ***Inclusion of the curriculum of some specific professionally oriented courses, knowledge from another science or another scientific field***

In the Physics curriculum, Bachelor Program **in the Craiova University** there are courses in Mathematics given by the lectures from Mathematics department, Anatomy given by lectures from Medicine and Pharmacy University, Chemistry given by lectures from the Chemistry Department, Programming and working with data bases given by specialists from Computer Science department. The language of sciences is mathematics, and it is normal to have such a collaboration. Medical Physicists need to know to read and understand a computed tomography and a collaboration at bachelor program with academic staff from Medicine is mandatory. Also, there are courses in Physics at engineering programs. As tendency, the number of practical applications and laboratories classes decreased significant during last 10 years. The explanation is to decrease the costs with staff, in the framework of finance per capita in Romania.

In the Electrical and Electronical curriculum, Bachelor Program in the **ATU**, there are courses in Mathematics given by the lectures from the Materials Engineering department, and Environmental Problems given by lectures in the Bioengineering department. In the mechanical engineering department Mining History is given by lectures from the Mining and Mineral Processing

Engineering. In the industrial engineering department, there are courses in introduction to economics and world economy given by academics in the business administration department.

In the curricula of the physics and engineering majors of the **Faculty of Physics and Technology of the PU**, study disciplines are included, the content of which has an inter-disciplinary nature. The knowledge that is obtained in mathematics courses is the language in which the physical phenomena and regularities and the theoretical foundations of telecommunication technologies are taught.

Many of our engineering majors also require knowledge of chemistry, which, apart from being a separate study discipline, is included in the content of specific disciplines. This applies in full force to the "Eco-energy technologies" specialty. The content of most disciplines in the Medical Physics major is closely related to knowledge of human biology, anatomy and physiology. This knowledge and some practical skills are formed in the laboratories of the Faculty of Biology by qualified persons in the field of biological and medical sciences.

The teaching of some academic disciplines, which are related to the preparation of students from the "

Telecommunications with Management" specialty, is carried out in the context of some social sciences such as - management, business communication, labour law and the basics of human relations (public relations). The faculty are qualified persons from the Faculty of History and Social Sciences at the university. Some of these classes are co-taught with students from their majors, which provides an opportunity for our students to interact with them and discuss common topics.

- ***Work on integrative projects***

UCv has few integrative research projects where students from PhD program are included. PhD students from Chemistry and Physics collaborate frequently. It is very important for students to collaborate because will listen other opinions, notice the same issue from many angles. These common experiences might become the basis of some future research connexions and the key for multidisciplinary projects.

There are collaborations with Engineering Faculties and Chemistry Department, bachelor students from these faculties using Physics laboratories and mutual. Another type of integrative projects that were developed at the UCv is represented by the projects of volunteering, sponsored by different local companies. For example, students from Physics, Journalism and Medicine developed campaigns in mass-media about the importance of a clean air for population' s health or about how important is the ophthalmologic screening in detecting vision issues at early ages and preventing early school leaving. Moreover, students become more responsible and active in their communities.

Summer schools from this Erasmus+ project might be an opportunity to involve international students from Science, Computer Science and Engineering in a common effort to understand how is made and working a sensor for air quality monitoring. Students will practice under academic staff supervision, making such a sensor, programming, connecting sensor to a European independent network of sensors, data collecting, processing and analysing. In the same time, during these summer schools, students meet specialists from different fields connected with environment protection.

ATU has several integrative research projects in which students from different faculties find space to work together. Students from computer engineering, software engineering, and electrical and electronic engineering departments often collaborate. Collaboration of students is very beneficial. Because students from different departments come together and take part in the same project, giving a different perspective. Such collaborations can be the foundation of future research and an important input to multidisciplinary projects. In addition, there may be projects in which mechanical engineering and energy systems engineering students participate jointly. In addition, students from different faculties have the opportunity to take part in a joint project with companies with which the university has contracted, through applied training.

The summer school in this Erasmus+ project is an important opportunity to involve students from different departments of the Engineering faculty in a joint project to understand how a sensor works. Students will be able to present their ideas on how sensors work from many perspectives, presenting different perspectives.

PU has conditions that stimulate the integrative nature of scientific projects that apply for university funding. There is also a certain quota for funding student projects only. FPT students have won competitions for this type of funding many times. Such projects are: "Bio polyelectrolyte nanoparticles for immobilization and controlled release of curcumin", "Building a laboratory for simulation and experimental research in electrical engineering", "Design, Analysis and Fabrication of CNC Router Rotary Table Realizing Fourth and Fifth Axis", "Building a system of educational Internet resources in physics and evaluating its didactic value".

Every year, university-wide scientific research projects receive special funding, in which the condition is that specialists from more than one faculty participate and, accordingly, there is a reserved quota for the participation of students and doctoral students. In recent years, one such project was the "Bio design and Bio economy" project for the "University Projects - Green Technologies" competition. In this project, the participants are from 7 faculties of PU.

The joint work of scientists and students on an interdisciplinary project is an example of an activity of an integral nature. Solving separate tasks that combine topics from several scientific fields gives students the opportunity not only to get a broad overview of the areas of application of their professional training, but also forms their vision of the integral nature of modern science and technology.

Students of the **Faculty of Natural Sciences UMB** are invited to participate at the interdisciplinary projects conducting in collaboration of several departments of the faculty. A collaboration between the Department of Computer Science and Departments of Chemistry and Biology is the most common and fruitful. Some of its results were introduced in the Chapter 1.

Some options for future development of integrability in the four universities

The level of integration can be improved during next years. International courses for students and academic staff, exposure to diverse approaches, exchange of good practices are real chances to intensify this process.

In the framework of this Erasmus+ project (code 2021-1-RO01-KA220-HED-000030286, Applying some advanced technologies in teaching and research, in relation to air pollution) will be organized **three international courses** for academic staff in "*The capabilities of the technology of augmented reality on mobile devices within the process of data acquisition*", "*Introduction in AI and statistics with practical examples*" and "*An introduction in ML and a practical demonstration about how can be used ML technology for the modelling of radiation emitted by green sources of energy*".These courses will represent an opportunity for researchers to work together, to exchange ideas, to find new things regarding advanced technologies that might help them in their research.

Academic staff will visit some facilities from other universities, to find solutions to apply together on other projects or to develop different research studies.

„If our small minds, for some convenience, divide this glass of wine, this universe, into parts — physics, biology, geology, astronomy, psychology, and so on — remember that nature does not know it!" [Source: https://quotepark.com/quotes/1921667-richard-feynman-if-our-small-minds-for-some-convenience-divide-t/]. We agree that if we want to understand the nature, we have to start thinking in an integrative way.

During next years, **ATU** will be able to integrate students from other departments and universities. This integration is made possible by the current project. Organizing foreign courses and summer schools for students and academic staff as part of the initiative, for example, improves integration.

In **Bulgaria**, the National Accreditation Agency' requirements for modernizing the educational process are directly related to the introduction of the competence approach. The formation of the key competences and those related to the professional direction should be the result of the studies in the bachelor's degree. This necessitates a new look at the curricula and their corresponding educational content, which will lead to strengthening their integral character. Any modernization of the educational content in physics and in engineering specialties is related to the latest achievements in science and technology, and these in themselves are predominantly integrative in nature.

The rules of the project activity at the **PU** will continue to tolerate a project of an integrative nature with students' participation, which will ensure sustainability in the trend for the integral nature in the education of future physicists and engineers.

Both, formal and content integrations, have been applied in newly accredited study programmes at the **Faculty of Natural Sciences, UMB.** Several study programmes have been introduced that are integrative by their nature. Students at all study levels can choose from a wide range of integrative courses that aim to develop their general knowledge, soft skills and life competences, such as mathematical or English language skills, financial literacy, management and communication skills, green competences, competences to use digital and other advanced technologies etc. Creating study groups of students of various specialisations have brought valuable exchange of views and ideas and contributed to the development of student critical thinking. Thus, the integration approaches have contributed to the training and education of "integrative" personalities that will contribute to the development of the society in the future.

In the literature there are the articles describe also **negative results** from the application of the integrative approach, such as the lack of systematicity that characterizes scientific knowledge and the superficiality of preparation, since theoretical thinking is not formed in sufficient completeness. It is believed that interactivity is difficult to combine with the consistency and orderly logic of scientific knowledge in the subject (Thibaut L. et al., 2018, Lamanauskas & Vilkoniene, 2008, Lamanauskas, 2009).

The world experience in applying the integrative approach in education is diverse, rich and specific for each country. There is no country whose experience in integrating education has been extremely effective or completely ineffective. Borrowing from the experience of other countries needs in-depth analysis and skilful adaptation to our educational traditions and opportunities.

The opportunities for integration into learning are significantly enriched after the educational changes related to online learning. Faculty and students were in a situation that allowed them to become familiar with the various educational resources offered on the Internet and to appreciate the potential for communication and information exchange that social networks offer. This is an opportunity for new cooperation and influences the level of integration between different educational institutions and individual faculty.

The integrative approach has a special place in science and engineering students' education, both in the pre-pandemic period and after. The new learning conditions caused by the impact of SMART technologies reinforce the importance of integration in the organization and conduct of a modern learning process. The effectiveness of implementation of an integrative approach in education mainly depends on the professional competencies of the educators, as well as on their conscious motivation to apply it.

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CHAPTER 4

INVOLVEMENT OF STUDENTS IN RESEARCH

4.1. Always an up-to-date approach to training future engineers and scientists (Ece Yilmaz, Hasan Yildizhan, Zhelyazka Raykova)

The modern engineering profession constantly deals with uncertainty, missing data, and competing demands from customers, governments, environmental groups, and the general public. It demands both interpersonal and technical abilities. Engineers of today must deal with constant technical and organizational change in the workplace while also attempting to include more "human" abilities into their knowledge bases and professional practices. They also have to cope with the business realities of modern industrial practice as well as the legal implications of every professional decision they make. Despite these obstacles, the prevailing style of engineering education is still the same as it was in the 1950s. Chalk and talk, big classrooms, and single-disciplinary lecture-based presentations were the norms, particularly in the early years of study. Advances in student-centered learning, such as problem-based and project-based learning, have had only a little impact on general engineering education thus far (Mills & Treagust, 2003).

The most crucial aspect of engineering education is determining the graduates' knowledge level. Engineering education programs can produce qualified graduates if applied programs include some basic principles and quality control is conducted on a regular basis. Engineering education is aimed at improving design abilities and solving design challenges. Engineering should be viewed as a method of solving societal problems by moving from analysis to synthesis.

The following are the most essential problems to address in engineering education:

- To help students discover analytical solutions and alternatives to situations they will face.
- To provide general design concepts that can be used in a variety of situations.
- In laboratory lessons, emphasize the exploration of experimental methodologies.
- To enable graduates to solve technical challenges by combining their practical and analytical skills.
- To learn how to design using existing materials and systems while researching and developing alternative technologies.
- Getting graduates ready for postgraduate studies (Gençoğlu & Cebeci, 1999).

The inquiry approach (or learning by inquiry, learning by discovery, IBSE, research approach) is an important approach in science and engineering teaching. It is based on constructivist ideas in learning, according to which each learner should follow his own path of constructing and organizing his knowledge, which involves students in exploring topics and in using data as evidence to answer the questions posed (Crawford, 2000). The inquiry approach can be applied to all academic disciplines, but the most extensive research and application are in the study of sciences and engineering. Student research can be small or large in scale, including the entire cycle of scientific knowledge or only some of its elements. These may involve the use of digital resources or appropriate equipment, may be conducted in real-world settings or online, or a combination of both.

This approach has a leading role in the implementation of integrated learning in education. Integrative trends in education are directly related to methods that strongly activate the activity of students for researching complex problems from reality and to those that individualize education. In this sense, the research approach is most suitable for organizing a learning process of an integrative nature.

Learning by inquiry can be viewed in three ways:

1. *as an element of the curriculum that explains how science works*. Here it is useful to include academic disciplines that are content-oriented to methodological knowledge, philosophy of science, history of science, those related to

how to do a diploma thesis, master's thesis, etc. These conceptions of research reflect the philosophical nature of scientific knowledge. In this sense, the courses in scientometrics also apply here.

Learning through inquiry is an approach that provides a deep contextual understanding of the learning content, but also considers the research process as an element of the learning content. In applying this approach, students begin to understand how science is done and how scientists do their work.

2. *such as carrying out scientific research by the students themselves in the learning process*. Abilities to do scientific research include, formulating and asking questions, planning and designing experiments, collecting and processing data, using data, and linking data into evidence in constructing explanations. Instruction organized through the application of inquiry-based learning actually involves engaging students in the practice of science.
3. *as a type of pedagogical approach, or as the ability of educators to use inquiry-based learning in the classroom to uncover the essence of key scientific principles and concepts*.

In inquiry learning, discovery of knowledge is foregrounded, and everything else as a learning task, assessments, resources, learning environments, and instructional strategies, are designed to support learning through the processes of inquiry and discovery.

There are no clear and unequivocal recommendations, as well as strictly defined teaching strategies that characterize this approach. But nevertheless, there are some characteristic starting points, and marks that are typical for it and make it recognizable: appropriately formulated questions, problems, or scientific research scenarios, often formulated by the students themselves, conducting research in scientific laboratories or in the field, as well as of different types of research projects.

The main characteristics of inquiry-based learning can be summarized in the following statements:

- Learning process is organized as research and study of answers to questions or solutions to problems, which is carried out in cooperation with other students and with the help of ICT;
- Principles and regularities of scientific research are applied;
- It can be related to questions and problems, the answer and solution of which are open-ended;

- Knowledge is obtained based on student activity, critical and creative thinking;
- A new meaning is given to what has been learned and the level of depth of knowledge is raised;
- Practical skills are built and knowledge about the methods of scientific knowledge is formed;
- Social skills are built for sharing research results with peers and with a wider audience, working in a group, and conducting reflection;
- It is a key to the formation of motivation for learning (Millar, 1997).

Learning by inquiry according to Reece & Walker (2007) can be seen as a variant of active learning that includes problem-based learning. Expected achievements of students when applying this approach in the education of sciences and engineering can be grouped as follows:

- Gaining knowledge about facts, evidence, theories, and explanations;
- Formation and development of practical and research skills;
- Formation of the so-called "soft skills".

In 2009, technology faculties were added to the list of engineering schools alongside regular engineering faculty in Turkey. Students who graduate from technology faculties are awarded the title of engineering, just like those who graduate from engineering faculties, and there is no difference in terms of authority. The most significant difference between technology and engineering faculties is that technology faculties place a greater emphasis on practical training. The fact that the seventh semester of the last year of technological faculties is entirely dedicated to **internship education** is a clear indication of how important practice is. The one-semester internship training provided last year was a critical chance for engineering candidate students to put their theoretical knowledge into reality. Because they have established their practical knowledge and foresee the business climate in the industry after they graduate, students who walk into a form of business life during internship training will have little difficulty finding a job and adapting to the work they have started (Akgül, Uçar, Öztürk & Ekşi, 2013).

The world is undergoing dramatic changes and is being influenced by rapid transformations, which engineering education cannot resist. Furthermore, the nature of engineering practice is evolving, which has an impact on engineering education (Ribeiro & Mizukami 2005). It is stated that the teaching of students by active researchers and their direct involvement in the research process is a very useful form of learning. Therefore, integrating research and education has been a major concern for both governments and academics on a global scale (Healey, Jordan, Pell & Short, 2010).

The form of research–learning integration can be specific, or it can be more broad or indirect in nature. For instance, when academic staff members' research pursuits are interwoven into their teaching activities in some way. On the other hand, the research–learning relationship is frequently ambiguous. Academics provide a more general perspective on the subject, the process of knowledge creation, and the teaching situation, rather than specific methodologies, discoveries, and experiences linked with specific research endeavors. Furthermore, research may be included in instructional activities in a weak or strong manner. The first case may be observed when academic staff members' research is used as teaching material in classrooms. In contrast, where research is more completely incorporated, students' learning activities are consciously shaped by it. Academic staff members' research and scientific activity become a structural aspect of the learning process for students, rather than just a piece of knowledge (Griffiths, 2004).

A study on students' awareness, experiences, and perceptions of research has shown that students realized the benefits of staff research in terms of their learning, such as being taught by motivated faculty, increased staff legitimacy, and the reflected glory of being taught by well-known researchers. Students recognized that when they were actively involved in research projects, their understanding of the nature of research and the development of research skills increased the most. Some of the students believed that participating in research activities would help them find work in the future (Healey et al., 2010). Active learning affects and improves students' exam grades. One study shows that active learning leads to increases in exam performance that raise average grades by half a letter. In addition, the study shows that failure rates in traditional lectures increase by 55% compared to the rates observed under active learning (Freeman et al., 2014).

12 days after March 11, 2020, when the first case was seen in Turkey, many institutions started online distance education on March 23, 2020, upon the recommendation of YÖK (Higher Education Board in Turkey). When the pandemic period training given in higher education institutions is examined,

it is seen that the institutions continue on their way with the existing distance education systems and transfer face-to-face training to this system (Durak, Çankaya, and İzmirli, 2020).

Distance education is a process in which synchronous (live lectures, webinars, online chats, etc.) and asynchronous (recorded videos, reading texts, events, discussion forums, etc.) activities are designed for a purpose. Although nowadays mostly designed with online processes, offline activities and learning materials are also part of distance education. Therefore, the elements and dimensions that make up the distance education ecosystem should be considered in the instructional design processes, and designs that will allow for meaningful learning experiences should be made instead of pure technology or purely synchronous activity-oriented applications (Bozkurt, 2020).

A study (Ceviz, Tektaş, Basmacı, Tektaş, 2020) provides opinions on the efficiency of distance education and its applicability in Turkey after the pandemic. This study was carried out with an online questionnaire with 997 students from various universities in Turkey. According to the results of the study, the students stated that they were not satisfied with the homework in distance education the most. 758 students (22.7%) did not want to be given homework; 689 students (20.63%) wanted homework not to be difficult, 568 students (17.01%) stated that they wasted a lot of time doing homework, 483 students (14.47%) wanted to use tools for distance education and a device (mobile phone, computer, tablet, laptop) to access the Internet at homeand they had to do their homework by phone, 345 students (10.33%) stated that the classroom environment was not suitable at home, 259 students (7.76%) stated that they had Internet interruptions, and 237 students (7.1%) stated that there was no Internet at all.

With the significant decrease in the impact of the pandemic on Turkey today, changes have occurred in education and training practices. Many universities have adopted the distance education techniques they have been applying due to the pandemic in their educational processes. For example, after the pandemic, some courses continued to be given online at ATU. Common compulsory courses such as Turkish Language, Atatürk's Principles, and Revolution History, called YÖK courses, are offered to students online.

It is possible to quickly put into action by eliminating some infrastructure deficiencies in the implementation of distance education in Turkey. In addition, this way, many students can be provided with educational opportunities, and individuals who cannot reach education due to various impossibilities are given the opportunity. An important opportunity will be created for willing students who have to work or live far from Universities and cannot go to the Campus for various reasons (Kılıç, 2020).

Cooperation with institutions in the field of distance education is also available for individuals who want to keep up with current advances in the field of STEM. Every institution can offer educational content on STEM areas such as the latest technology, engineering, and scientific advancement through the existing virtual platforms. As a result of distance education, STEM education expands its reach and reaches an ever-increasing number of people (Poyraz, 2018).

Distance education applications, which are widely used on the occasion of the pandemic, can also be integrated with STEM applications to train future engineers and scientists. Robotic-Based STEM Activities in Distance Education, Virtual Laboratory Applications Used within the Framework of Simultaneous Distance Education Model and STEM Education Activities Supported by Web 2.0 Tools, Augmented Reality Applications in the Distance Education Process applications are highly applicable education methods with distance education for engineering students. In this way, students will be able to develop themselves independently of the concept of time and space and will become highly qualified scientists in the future (Yılmaz, Akyol & Aydede, 2021).

An online education platform called BTK Academy can set an example for STEM distance STEM applications in Turkey. BTK Academy aims to raise the awareness of all segments of society, especially young people and children, by removing the barriers to accessing information in the field of science and technology in accordance with the changing educational methods and methods with the technological developments of the current century. It is a training center that aims to contribute to the production of the quality workforce needed by the public and private sectors and to transfer the current knowledge of the technology world to the public with a constantly renewing education approach, with the online training certificate programs it organizes (https://www.btkakademi.gov.tr/).

In order for students to improve themselves in the field they study practically, the Presidential Human Resources Office in Turkey started the Internship Mobilization application in 2020. Within the scope of this application, many students have the chance to use the theoretical knowledge they have acquired about the field they are studying in practice. Thus, students can participate in many projects and research carried out in the private or public sector.

In 2021, 172 people applied to this program from **ATU**. More than half of the applicant students have completed their internships in both the private sector and public institutions. Thanks to this program, which offers internship opportunities in public institutions, many engineering candidate students studying at ATU have had the opportunity to do internships in institutions such as "The Turkish Aerospace Industry", "TR Ministry of Industry And Technology", "Space Technologies Research Institute", etc. It gives students an opportunity to be involved in research, projects, and applications carried out in various engineering fields (https://www.kariyerkapisi.cbiko.gov.tr/).

The formation and development of research skills of students, future scientists, and engineers at the **Faculty of Physics and Technology, PU** in the pandemic and post-pandemic period of study is carried out by setting assignments that must be completed independently or in a group of students. In order to solve some of these assignments, students are required to conduct partial studies, as during the pandemic period of study they were predominantly theoretical. In the post-pandemic period, the selection of assignments also includes those of an experimental nature, focusing on the relevant educational or scientific laboratory.

A sure way for students to be involved in research work is to have them work on a thesis to complete their degree. Motivated students usually choose a thesis as a way to graduate. The change brought about by using online learning also affected the conduct of research by students. Their long stay on the Internet and their work with educational platforms made them more confident in the search for information on the researched topic and in the possibility of more intensive and frequent contact with the instructors. Online consultations are increasingly preferred, which can take place at the time and social media chosen by both parties.

Our experience has shown that the implementation of experimental research work in the relevant environment is accepted willingly by the students, given the impossibility of this happening two years ago.

Another possibility for conducting more practical work is the participation of our students in the National Project "Student Practices" (https://praktiki.mon.bg/), which is already functioning in its second phase. This project envisages the organization and financing of practical training for students in the real environment of various companies and research laboratories. Their interest in the program after the pandemic lockdown has greatly increased and the number of participants has increased by 35% compared to before 2020.

Conducting active learning is closely related to the application of inquiry learning. Engaging students, future engineers, and scientists in learning through research is an indispensable way for them to be well-prepared for the successful practice of their profession. The difficulties imposed by the pandemic period led to a rethinking of the meaning of this teaching approach in the direction of evaluating its significance and its connection with new technologies. In the partner universities participating in the project, the implementation of introductory training in the post-pandemic period is connected with a number of initiatives related to the practice and internships of students. Changes are also noted in the way inquiry training is conducted - more and more engagement with social networks and new technologies and positive emotions in experimental work.

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CONCLUSIONS

Over the past decade, the way we understand the learning process has undergone enormous changes. They are largely caused by technological progress and the rapid development of digitization. The COVID-19 pandemic caused changes in learning processes by orienting it to the use of new approaches and methods related to online communication. Faculty and students had to quickly adapt to this new situation, requiring specific digital skills and didactic knowledge. Science and engineering educators faced the additional challenge of conducting experimental classes in an online environment.

Experience has shown that the implementation of online learning made it possible to continue learning in the extreme conditions of the COVID-19 pandemic with varying degrees of success depending on the level of preparation of the educators and the availability of learning resources.

Faculty had to reorient their curricula and learning content to become experts in working with learning management systems by skilfully using existing technologies and being ready to learn new ones. Thus, this situation has caused faculty to enrich their teaching skills by developing their digital competences related to the educational process. It is also very important for them to navigate among the new opportunities offered by technology and the corresponding teaching methods and approaches in order to gain self-confidence and successfully carry out their educational activities.

The conditions of training during the COVID-19 pandemic-imposed forms of organization such as mixed and hybrid. Blended and hybrid learning are two different approaches, and their choice has different implications for students and the learning process that takes place. It is necessary for educators to know their characteristics and didactic possibilities described in the book to choose teaching approaches and methods based on the specific situation, considering the needs of the learner and the nature of the educational content.

We believe that both hybrid and blended learning have their own place in future of education as they can be made more and more effective as technology advances.

The experience of conducting blended and hybrid learning has shown that the implementation of the flipped classroom as an approach has a place in the future education of scientists and engineers. The characteristics of this approach, its advantages and disadvantages described in the book can serve the educators to implement an effective learning model that is highly student-oriented and stimulates them to interact actively and form the necessary professional competences.

The possibilities of artificial intelligence (AI) to influence education explored in this book convinced us that, while its application brings significant changes, it has a place in both online and traditional learning. Understanding the characteristics of AI and the problems that may arise in its use will help educators better prepare for the future application of AI in education. More and more countries are considering the development of AI technology as a national priority, and the place of this technology in education is becoming more and more significant.

Augmented reality has been evaluated as a relatively new technology with educational potential. With the help of "augmented reality" technology, context-sensitive learning can be provided, aimed at acquiring skills important to students in the sciences, medicine, engineering, and military. Various 3D models, visualized using marker-based augmented reality, have a place in modern education as they are used in studying the device and principle of operation of complex machines and apparatus.

A new technology of great importance to the higher education in science and engineering students is represented by the remote experiments. This method of experimentation plays a crucial role in online learning to form the experimental skills so necessary for these students. The method is based on the use of computer-based electronic laboratories available to any user with an Internet connection. Thus, students can conduct and control experiments with real components remotely. The research shows that applications for working in remote laboratories are becoming more and more advanced, which enable working with more diverse experimental tasks from different fields of science. Enriching and modernizing the teaching experience of scientists in universities requires them to focus on the possibilities of this technology to make attempts to organize learning in remote access laboratories.

Although gaining popularity before the COVID-19 pandemic, cloud technologies have become indispensable during the lockdown, especially in education. These technologies are one of the sought after and actively developed emerging areas of the modern IT world. The use of cloud technologies in higher education has provided great learning opportunities that the modern educator must be aware of. They provide easy collaboration between different administrative units, between Faculty and students, between educators and educators, and between students, and save money and time in the problem-solving process. Through them, the service is provided quickly and immediately, at different parts of the day and from different locations. In the experience shared in the book with the use of some educational platforms and applications in recent years (Zoom, Google classroom, Microsoft Teams, DIEPSEL), some of their didactic characteristics are described and an assessment of their advantages and disadvantages is made. This will help Faculty to navigate and enrich their digital skills in order to adapt their activities in the best possible way to the conditions of online learning.

The integrative trends in the education of future physicists and physics engineers discussed in the book are supported by examples from the educational practice of four universities, partners in the project "Applying some advanced technologies in teaching and research, in relation to air pollution". The opportunities for integrating learning that have emerged after the post-pandemic educational changes related to online learning are described and systematized. Faculty and students collaborate in a new way, use many and different learning resources, which greatly influenced the level of integration in all directions - organizationally and content-wise.

The application of the research approach in the training of future STEM specialists is not new to educational systems. The changes caused by the rapid introduction of new technologies in the training of future engineers and physicists created additional interest in this educational approach. This approach includes problem-based learning and project-based learning and plays a leading role in organizing an integrative learning process. Research-based learning is a variant of active learning in which students carry out scientific research and thus form the necessary professional competences. The good practices of some of the partners of the project "Applying some advanced technologies in teaching and research, in relation to air pollution" described in the book can provoke new ideas in the readers and appreciate the power and importance of the research approach in education.

We have witnessed numerous educational challenges posed by the pandemic that require attention. By addressing them we seek ways to explore and overcome them in the context of our experience and interest as educators of future engineers and scientists.

We share ideas that STEM education in universities faces several issues such as:

- How to organize better the learning process through an effective combination of hybrid and mixed form?
- How to most successfully integrate the new learning methods associated with SMART technologies with traditions in the training of STEM students?
- How to meet the social and emotional needs of Faculty and students from communication in an online environment?
- How to ensure objectivity and reliability in assessment in an online learning environment?
- How should the learning process react to unforeseen situations, which we hope will not be many and frequent?
- How can the formation of experimental skills of future engineers and scientists be supported by new technologies?
- and others.

We are convinced that not simply restoring the educational process to its pre-pandemic levels of functioning is a solution to these challenges, but rather the redirection to new forms of organization, the application of new approaches strongly related to new technologies defines the image of the modern post-pandemic education.